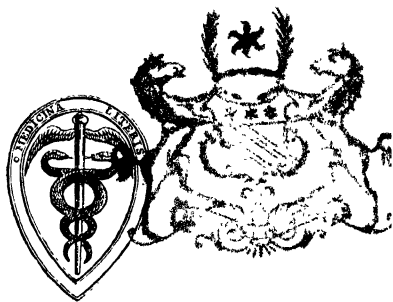


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A MANUAL
OF THE
ANATOMY OF VERTEBRATED
ANIMALS.

BY
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PREFACE.

THE present work is intended to provide students of comparative anatomy with a condensed statement of the most important facts relating to the structure of vertebrated animals, which have hitherto been ascertained. Except in a very few cases, I have intentionally abstained from burdening the text with references ; and, therefore, the reader, while he is justly entitled to hold me responsible for any errors he may detect, will do well to give me no credit for what may seem original, unless his knowledge is sufficient to render him a competent judge on that head.

About two-thirds of the illustrations are original, the rest* are copied from figures given by Agassiz, Bischoff, Burmeister, Busch, Carus, Dugès, Flower, Gegenbaur, Hyrtl, Von Meyer, Müller, Pander and D'Alton, Parker, Quatrefages, and Traquair.

A considerable portion of the book has been in type for

* Namely, Figures 1, 6, 10, 11, 12, 13, 15, 18, 23, 26, 28, 29, 30, 31, 36, 39, 41, 42, 46, 50, 51, 54, 55, 56, 57, 58, 59, 60, 61, 75, 79, 82, 101, 107, 108, 109, 110.

some years; and this circumstance must be my excuse for appearing to ignore the views of several valued contemporaries. I refer more especially to those contained in recently published works of Professors Flower and Gegenbaur.

London, September, 1871.

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THE ANATOMY OF VERTEBRATED ANIMALS.

CHAPTER I.

A GENERAL VIEW OF THE ORGANIZATION OF THE VERTEBRATA—THE VERTEBRATE SKELETON.

The Distinctive Characters of the Vertebrata.—The *Vertebrata* are distinguished from all other animals by the circumstance that a transverse and vertical section of the body exhibits two cavities, completely separated from one another by a partition. The dorsal cavity contains the cerebro-spinal nervous system; the ventral, the alimentary canal, the heart, and, usually, a double chain of ganglia, which passes under the name of the “sympathetic.” It is probable that this sympathetic nervous system represents, wholly or partially, the principal nervous system of the *Annulosa* and *Mollusca*. And, in any case, the central parts of the cerebro-spinal nervous system, viz. the brain and the spinal cord, would appear to be unrepresented among invertebrated animals. For these structures are the results of the metamorphosis of a part of the primitive epidermic covering of the germ, and only acquire their ultimate position, in the interior of the dorsal tube, by the development and union of outgrowths of the blastoderm, which are not formed in the *Invertebrata*.*

* It is possible that an exception to this rule may be found in the Ascidians. The tails of the larvæ of these animals exhibit an axial structure, which has a cer-

tain resemblance to a vertebrate notochord; and the walls of the pharynx are perforated, much as in *Amphioxus*.

Again, in the partition between the cerebro-spinal and visceral tubes, certain structures, which are not represented in invertebrated animals, are contained. During the embryonic condition of all vertebrates, the centre of the partition is occupied by an elongated, cellular, cylindroidal mass—the *notochord*, or *chorda dorsalis*. And this structure persists throughout life in some *Vertebrata*; but, in most, it is more or less completely replaced by a jointed, partly fibrous and cartilaginous, and partly bony, *vertebral column*.

In all *Vertebrata*, that part of the wall of the visceral tube which lies at the sides of, and immediately behind, the mouth, exhibits, at a certain stage of embryonic development, a series of thickenings, parallel with one another and transverse to the axis of the body, which may be five or more in number, and are termed the *visceral arches*. The intervals between these arches become clefts, which place the pharyngeal cavity, temporarily or permanently, in communication with the exterior. Nothing corresponding with these arches and clefts is known in the *Invertebrata*.

A vertebrated animal may be devoid of articulated limbs, and it never possesses more than two pairs. These are always provided with an internal skeleton, to which the muscles moving the limbs are attached. The limbs of invertebrated animals are commonly more numerous, and their skeleton is always external.

When invertebrated animals are provided with masticatory organs, the latter are either hard productions of the alimentary mucous membrane, or are modified limbs. Vertebrated animals also commonly possess hard productions of the alimentary mucous membrane in the form of teeth; but their jaws are always parts of the walls of the parietes of the head, and have nothing to do with limbs.

All vertebrated animals have a complete vascular system. In the thorax and abdomen, in place of a single perivisceral cavity in communication with the vascular system, and serving as a blood-sinus, there are one or more serous sacs. These invest the principal viscera, and may or may

not communicate with the exterior—recalling, in the latter case, the atrial cavities of *Mollusca*.

In all *Vertebrata*, except *Amphioxus*, there is a single valvular heart, and all possess a *hepatic portal system*; the blood of the alimentary canal never being wholly returned directly to the heart by the ordinary veins, but being more or less completely collected into a trunk—the *portal vein*, which ramifies through and supplies the liver.

The Development of the Vertebrata.—The ova of *Vertebrata* have the same primary composition as those of other animals, consisting of a *germinal vesicle*, containing one or many *germinal spots*, and included within a *vitellus*, upon the amount of which the very variable size of the vertebrate ovum chiefly depends. The vitellus is surrounded by a *vitelline membrane*, and this may receive additional investments in the form of layers of *albumen*, and of an outer, coriaceous, or calcified *shell*.

The *spermatozoa* are always actively mobile, and, save in some rare and exceptional cases, are developed in distinct individuals from those which produce ova.

Impregnation may take place, either subsequently to the extrusion of the egg, when, of course, the whole development of the young goes on outside the body of the *oviparous* parent; or it may occur before the extrusion of the egg. In the latter case, the development of the egg in the interior of the body may go no further than the formation of a patch of primary tissue; as in birds, where the so-called *cicatricula*, or “tread,” which is observable in the new-laid egg, is of this nature. Or, the development of the young may be completed while the egg remains in the interior of the body of the parent, but quite free and unconnected with it; as in those vertebrates which are termed *ovoviviparous*. Or, the young may receive nourishment from its *viviparous* parent, before birth, by the close apposition of certain vascular appendages of its body to the walls of the cavity in which it undergoes its development.

The vascular appendages in question constitute the chief

part of what is called the *placenta*, and may be developed from the umbilical vesicle (as in *Mustelus* among Sharks), or from the allantois and chorion (as in most mammals). At birth, they may be either simply detached from the substance of the parental organism, or a part of the latter may be thrown off along with them and replaced by a new growth. In

Fig. 1.

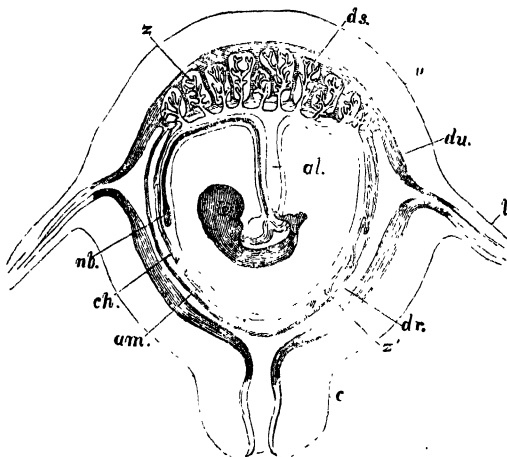


Fig. 1. -Diagrammatic section of the pregnant uterus of a deciduate placental mammal (*Homo*): *u*, uterus; *l*, Fallopian tube; *c*, neck of the uterus; *du*, uterine decidua; *ds*, *decidua serotina*; *dr*, *decidua reflexa*; *z*, *z'*, villi; *ch*, chorion; *am*, amnion; *nb*, umbilical vesicle; *al*, allantois.

the highest vertebrates, the dependence of the young upon the parent for nutrition does not cease even at birth; but certain cutaneous glands secrete a fluid called *milk*, upon which the young is fed for a longer or shorter time.

When development takes place outside the body, it may be independent of parental aid, as in ordinary fishes; but, among some reptiles and in most birds, the parent supplies

the amount of heat, in excess of the ordinary temperature of the air, which is required, from its own body, by the process of *incubation*.

The first step in the development of the embryo is the division of the vitelline substance into *cleavage-masses*, of which there are at first two, then four, then eight, and so on. The germinal vesicle is no longer seen, but each cleavage-mass contains a *nucleus*. The cleavage-masses eventually become very small, and are called *embryo-cells*, as the body of the embryo is built up out of them. The process of yelk-division may be either *complete* or *partial*. In the former case, it, from the first, affects the whole yelk; in the latter, it commences in part of the yelk, and gradually extends to the rest. The *blastoderm*, or embryogenic tissue in which it results, very early exhibits two distinguishable strata—an inner, the so-called *mucous stratum* (*hypoblast*), which gives rise to the epithelium of the alimentary tract; and an outer, the *serous stratum* (*epiblast*), from which the epidermis and the cerebro-spinal nervous centres are evolved. Between these appears the *intermediate stratum* (*mesoblast*), which gives rise to all the structures (save the brain and spinal marrow) which, in the adult, are included between the epidermis of the integument and the epithelium of the alimentary tract and its appendages.

A linear depression, the *primitive groove* (Fig. 2, A, *c*), makes its appearance on the surface of the blastoderm, and the substance of the mesoblast along each side of this groove grows up, carrying with it the superjacent epiblast. Thus are produced the two *dorsal laminæ*, the free edges of which arch over towards one another, and eventually unite, so as to convert the primitive groove into the cerebro-spinal canal. The portion of the epiblast which lines this, cut off from the rest, becomes thickened, and takes on the structure of the brain, or *Encephalon*, in the region of the head; and of the spinal cord, or *Myelon*, in the region of the spine. The rest of the epiblast is converted into the epidermis.

THE ANATOMY OF VERTEBRATED ANIMALS.

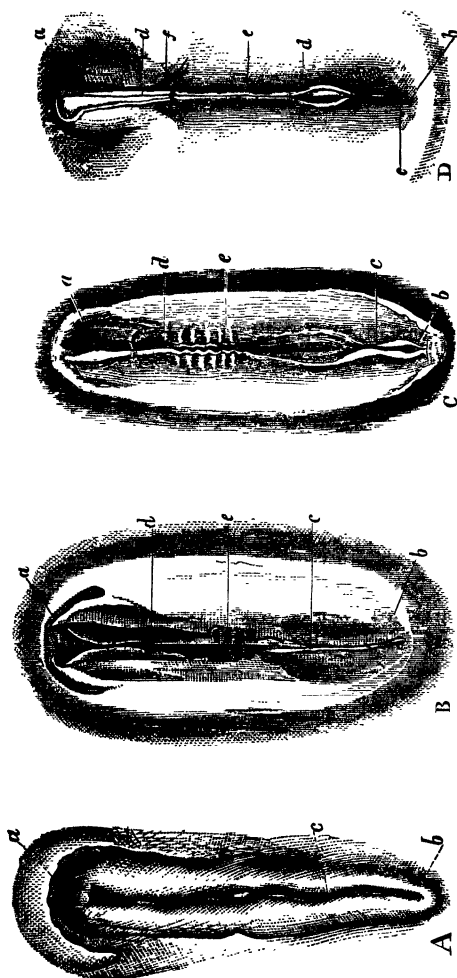


Fig. 2.—The early stages of the development of the body of a Fowl.—A, the first rudiment of the embryo; *a* its cephalic, *b* its caudal, end; *c*, the primitive groove.—B, the embryo further advanced; *a*, *b*, *c*, as before; *d*, the dorsal laminae as yet developed only in the cephalic region, and not quite united in the middle line; *e*, the proto-vertebrae.—C, the letters as before. The dorsal laminae have united throughout the greater part of the cephalic region, and are beginning to unite in the anterior spinal region.—D, embryo further advanced (the second day of incubation), the dorsal laminae having united throughout nearly their whole length. The protovertebrae have increased in number, and the omphalomesenteric veins, *f*, are visible. The embryos are drawn of the same absolute length, but, in nature, the older are longer than the younger.

The part of the blastoderm which lies external to the dorsal laminae forms the *ventral laminae*; and these bend downwards and inwards, at a short distance on either side of the dorsal tube, to become the walls of a ventral, or visceral, tube. The ventral laminae carry the epiblast on their outer surfaces, and the hypoblast on their inner surfaces, and thus, in most cases, tend to constrict off the central from the peripheral portions of the blastoderm. The latter, extending over the yolk, incloses it in a kind of bag. This bag is the first-formed and the most constant of the temporary, or foetal, appendages of the young vertebrate, the *umbilical vesicle*.

While these changes are occurring, the mesoblast splits, throughout the regions of the thorax and abdomen, from its ventral margin, nearly up to the *notochord* (which has been developed, in the meanwhile, by histological differentiation of the axial indifferent tissue, immediately under the floor of the primitive groove), into two *lamellae*. One of these, the *visceral lamella*, remains closely adherent to the hypoblast, forming with it the *splanchnopleure*, and eventually becomes the proper wall of the enteric canal; while the other, the *parietal lamella*, follows the epiblast, forming with it the *somatopleure*, which is converted into the parietes of the thorax and abdomen. The point of the middle line of the abdomen at which the somatopleures eventually unite, is the *umbilicus*.

The walls of the cavity formed by the splitting of the ventral laminae acquire an epithelial lining, and become the great *pleuroperitoneal* serous membranes.

The Foetal Appendages of the Vertebrata.—At its outer margin, that part of the somatopleure which is to be converted into the thoracic and abdominal wall of the embryo, grows up anteriorly, posteriorly, and laterally, over the body of the embryo. The free margins of this fold gradually approach one another, and, ultimately uniting, the inner layer of the fold becomes converted into a sac filled with a clear fluid, the *Amnion*; while the outer layer either disappears, or coa-

lesces with the vitelline membrane, to form the *Chorion* (Fig. 3).

Fig. 3.

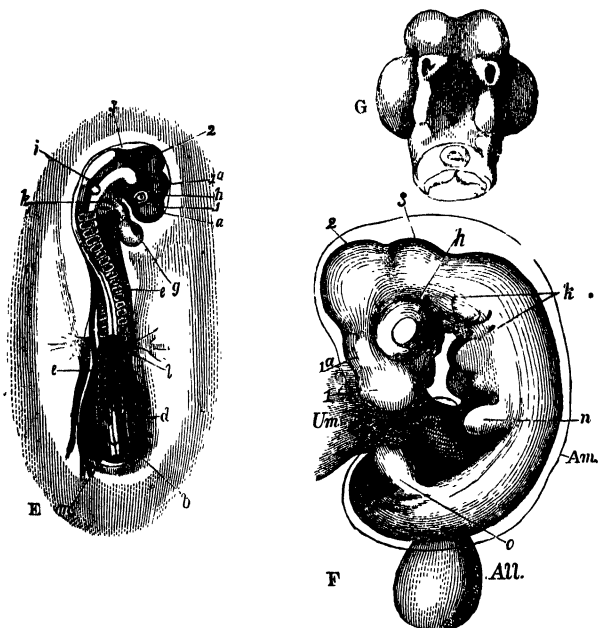


Fig. 3.—Later stages of the development of the body of a Fowl than those represented in Fig. 2.—E, embryo at the third day of incubation; *g*, heart; *h*, eye; *i*, ear; *k*, visceral arches and clefts; *l*, *m* anterior and posterior folds of the amnion which have not yet united over the body; 1, 2, 3, first, second, and third cerebral vesicles; 1*a* vesicle of the third ventricle.—F, embryo at the fifth day of incubation. The letters as before, except *n*, *o*, rudiments of the anterior and posterior extremities; *Am*, amnion; *All* (the allantois, hanging down from its pedicle); *Um*, umbilical vesicle.—G, under-view of the head of the foregoing, the first visceral arch being cut away.

Thus the amnion incloses the body of the embryo, but not the umbilical sac. At most, as the constricted neck

which unites the umbilical sac with the cavity of the future intestine, becomes narrowed and elongated into the *vitelline duct*, and as the sac itself diminishes in relative size, the amnion, increasing in absolute and relative dimensions, and becoming distended with fluid, is reflected over it (Fig. 1).

A third foetal appendage, the *Allantois*, commences as a single, or double, outgrowth from the under-surface of the mesoblast, behind the alimentary tract; but soon takes the form of a vesicle, and receives the ducts of the *primordial kidneys*, or *Wolffian bodies*. It is supplied with blood by two arteries, called *hypogastric*, which spring from the aorta; and it varies very much in its development. It may become so large as to invest all the rest of the embryo, in the respiratory, or nutritive, processes of which it then takes an important share.

The splitting of the ventral laminae, and the formation of a pleuroperitoneal cavity, appear to take place in all *Vertebrata*. Usually, there is a more or less distinct umbilical sac; but in fishes and *Amphibia* there is no amnion; and the allantois, if it is developed at all, remains very small in these two groups.

Reptiles, birds, and mammals have all these foetal appendages. At birth, or when the egg is hatched, the amnion bursts and is thrown off, and so much of the allantois as lies outside the walls of the body, is similarly exuviated; but that part of it which is situated within the body is very generally converted, behind and below, into the urinary bladder, and, in front and above, into a ligamentous cord, the *urachus*, which connects the bladder with the front wall of the abdomen. The umbilical vesicle may either be cast off, or taken into the interior of the body and gradually absorbed.

The majority of the visceral clefts of fishes and of many *Amphibia* remain open throughout life; and the visceral arches of all fishes (except *Amphioxus*), and of all *Amphibia*, throw out filamentous or lamellar processes, which receive branches from the aortic arches, and, as *branchiae*, subserve

respiration. In other *Vertebrata* all the visceral clefts become closed and, with the frequent exception of the first, obliterated; and no branchiæ are developed upon any of the visceral arches.

In all vertebrated animals, a system of relatively, or absolutely, hard parts affords protection, or support, to the softer tissues of the body. These, according as they are situated upon the surface of the body, or are deeper-seated, are called *exoskeleton*, or *endoskeleton*.

The Vertebrate Endoskeleton.—This consists of connective tissue, to which cartilage and bone may be added in various proportions; together with the tissue of the notochord and its sheath, which cannot be classed under either of these heads. The endoskeleton is distinguishable into two independent portions—the one *axial*, or belonging to the head and trunk; the other, *appendicular*, to the limbs.

The *axial endoskeleton* usually consists of two systems of skeletal parts, the *spinal system*, and the *cranial system*, the distinction between which arises in the following way in the higher *Vertebrata*.

The primitive groove is, at first, a simple straight depression, of equal diameter throughout; but, as its sides rise, and the dorsal laminae gradually close over (this process commencing in the anterior moiety of their length, in the future cephalic region), the one part becomes wider than the other, and indicates the cephalic region (Fig. 4, A). The notochord, which underlies the groove, terminates in a point, at a little distance behind the anterior end of the cephalic enlargement, and indeed under the median of three dilations which it presents. So much of the floor of the enlargement as lies in front of the end of the notochord, bends down at right angles to the rest; so that the anterior enlargement, or *anterior cerebral vesicle*, as it is now called, lies in front of the end of the notochord; the median enlargement, or the *middle cerebral vesicle*, above its extremity; and the hinder enlargement, or the *posterior cerebral vesicle*, behind that extremity (Fig. 4, D and E). The under-

surface of the anterior vesicle lies in a kind of pit, in front of, and rather below, the apex of the notochord, and the *pituitary gland* is developed in connection with it. From the opposite upper surface of the same vesicle the *pineal gland* is evolved, and the part of the anterior cerebral vesicle in connection with which these remarkable bodies arise, is the future *third ventricle*.

Behind, the posterior cerebral vesicle passes into the primitively tubular spinal cord (Fig. 4, A). Where it does so, the head ends, and the spinal column begins; but no line of demarcation is, at first, visible between these two, the indifferent tissues which ensheath the notochord passing, without interruption, from one region to the other, and retaining the same character throughout.

The first essential differentiation between the skull and the vertebral column is effected by the appearance of the *protovertebræ*. At regular intervals, commencing at the anterior part of the cervical region, and gradually extending backwards, the indifferent tissue on each side of the notochord undergoes a histological change, and gives rise to more opaque quadrate masses, on opposite sides of the notochord (Fig. 2, B, C). Each pair of these gradually unite above and below that structure, and send arched prolongations into the walls of the spinal canal, so as to constitute a *protovertebra*.

No *protovertebræ* appear in the floor of the skull, so that, even in this early stage, a clear distinction is drawn between the skull and the spinal column.

The Spinal System.—The *protovertebræ* consist at first of mere indifferent tissue; and it is by a process of histological differentiation within the *protovertebral* masses, that, from its deeper parts, one of the *spinal ganglia* and a *cartilaginous vertebral centrum*,—from its superficial layer, a *segment of the dorsal muscles*, are produced.

Chondrification extends upwards into the walls of the dorsal tube, to produce the *neural arch* and *spine* of each *vertebra*; and, outwards, into the wall of the thoracic and

Fig. 4.

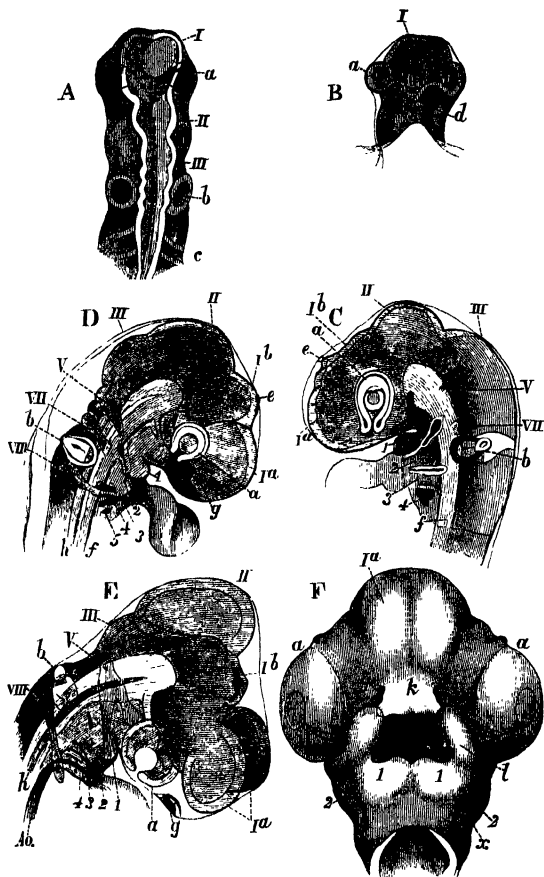


Fig. 4.—Successive stages of the development of the head of a Chick. I, II, III, first, second, and third cerebral vesicles; Ia, vesicle of the cerebral hemisphere; Ib, vesicle of the third ventricle; a, rudiments of the eyes and optic nerves; b, of the ears; g, of the olfactory

organs; *d*, the infundibulum; *e*, the pineal gland; *c*, protovertebræ; *h*, notochord; 1, 2, 3, 4, 5, visceral arches; V, VII, VIII, the trigeminal, portio dura, and ninth and tenth pairs of cranial nerves; *k*, the nasal process; *l*, the maxillary process; *x*, the first visceral cleft. A, B, upper and under views of the head of a Chick at the end of the second day. C, side-view at the third day. D, side-view at seventy-five hours. E, side-view of the head of a Chick at the fifth day, which has been subjected to slight pressure. F, head of a Chick at the sixth day, viewed from below.

abdominal part of the ventral tube, to give rise to the *transverse processes* and *ribs*. In fishes, the latter remain distinct and separate from one another, at their distal ends; but, in most reptiles, in birds, and in mammals, the ends of some of the anterior ribs, on both sides, unite together, and then the united parts coalesce in the middle line to form a median subthoracic cartilage—the *sternum*.

When ossification sets in, the centra of the vertebræ are usually ossified, in great measure, from ringlike deposits which closely invest the notochord; the arches, from two lateral deposits, which may extend more or less into the centrum. The vertebral and the sternal portions of a rib may each have a separate ossific centre, and become distinct bones; or the sternal parts may remain always cartilaginous. The sternum itself is variously ossified.

Between the completely ossified condition of the vertebral column and its earliest state, there are a multitude of gradations, most of which are more or less completely realised in the adult condition of certain vertebrated animals. The vertebral column may be represented by nothing but a notochord with a structureless, or more or less fibrous, or cartilaginous sheath, with or without rudiments of cartilaginous arches and ribs. Or there may be bony rings, or ensheathing ossifications, in its walls; or it may have ossified neural arches and ribs only, without cartilaginous or osseous centra. The vertebræ may be completely ossified, with very deeply biconcave bodies, the notochord remaining persistent in the doubly conical intervertebral substance; or, ossification may extend, so as to render the centrum concave on one surface and convex on the other, or even convex at each end.

Vertebræ which have centra concave at each end have been conveniently termed *amphicæulous*; those with a cavity in front and a convexity behind, *procæulous*; where the position of the concavity and convexity is reversed, they are *opisthocæulous*.

In the *Mammalia*, the centra of the vertebræ are usually flat at each end, the terminal faces being discoidal *epiphyses*, developed from centres of ossification distinct from that of the centrum itself.

The centra of the vertebræ may be united together by synovial joints, or by ligamentous fibres—the *intervertebral ligaments*. The arches are connected by ligaments, and generally, in addition, by overlapping articular processes called *zygapophyses*, or oblique processes.

In a great many *Vertebrata*, the first and second cervical, or *atlas* and *axis*, vertebræ undergo a singular change; the central ossification of the body of the atlas not coalescing with its lateral and inferior ossifications, but either persisting as a distinct *os odontoideum*, or ankylosing with the body of the axis, and becoming the so-called *odontoid process* of this vertebra.

In *Vertebrata* with well-developed hind limbs, one or more vertebræ, situated at the posterior part of the trunk, usually become peculiarly modified, and give rise to a *sacrum*, with which the pelvic arch is connected by the intermediation of expanded and ankylosed ribs. In front of the sacrum the vertebræ are artificially classed as *cervical*, *dorsal*, and *lumbar*. The first vertebra, the ribs of which are connected with the sternum, is *dorsal*, and all those which lie behind it, and have distinct ribs, are *dorsal*. Vertebrae without distinct ribs, between the last dorsal and the sacrum, are *lumbar*. Vertebrae, with or without ribs, in front of the first dorsal are *cervical*.

The vertebræ which lie behind the sacrum are *caudal* or *coccygeal*. Very frequently, downward processes of these vertebræ inclose the backward continuation of the aorta, and may be separately ossified as *subcaudal*, or chevron, bones.

A tolerably complete segment of the spinal skeleton may be studied in the anterior part of the thorax of a crocodile (Fig. 5). It presents a procœlous vertebral *centrum* (*C*), united with which by the *neurocentral suture* is the *neural arch*, which rises into the *neural spine* (*N.S.*). Two processes, the *prezygapophyses* (*Z*), extend from the front part of the arch, and have flat articular surfaces turned dorsally. Two others of similar form, but having their articular surfaces turned ventrally, proceed from the posterior face of the neural arch, and are the *postzygapophyses* (*Z'*). By these, which are

Fig. 5.

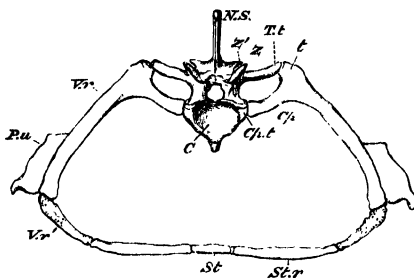


Fig. 5.—A segment of the endoskeleton in the anterior thoracic region of the body of a Crocodile.—*C*, the centrum or body of the vertebra; *N.S.*, the neural spine; *Z*, the prezygapophysis; *Z'*, the postzygapophysis; *T.t*, the transverse process which articulates with the tuberculum of the rib (*t*); *Cp.t*, that which articulates with the capitulum of the rib (*Cp*); *V.r*, the ossified vertebral rib; *V.r'*, the part of the vertebral rib which remains cartilaginous; *St.r*, the sternal rib; *St*, an artificially separated segment of the sternum; *P.u*, the uncinate process.

often called oblique, or articular, processes, the vertebra articulates with the corresponding processes of its predecessor or successor in the series. The *transverse processes* are two on each side, one superior and one inferior. The former (*T.t*) articulates with the *tuberculum* of the rib, the latter (*Cp.t*) with its *capitulum*. They may, therefore, be called *capitular* and *tubercular transverse processes* respectively. Each rib is divided by an articulation into

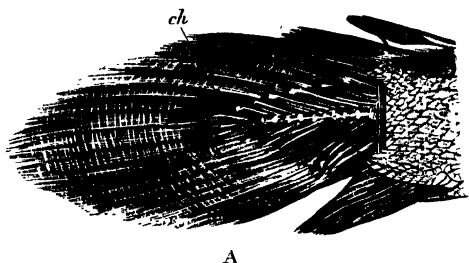
a vertebral (*V.r*) and a sternal (*St.r*) part. The former remains unossified for a considerable distance at its distal end (*V.r'*); the latter is more or less converted into cartilage bone. The proximal end of the vertebral rib bifurcates into a *tuberculum* (*t*) and a *capitulum* (*Cp*). The distal end of the sternal rib unites with the more or less ossified but unsegmented cartilage, which forms the sternum (*St*). A cartilaginous, or partly ossified, *uncinate process* (*P.u*) projects from the posterior edge of the vertebral rib, over the intercostal space. The student will find it convenient to familiarise himself with the conception of such a spinal segment as this, as a type, and to consider the modifications hereafter described with reference to it.

In the majority of the *Vertebrata*, the caudal vertebræ gradually diminish in size towards the extremity of the body, and become reduced, by the non-development of osseous processes or arches, to mere centra. But, in many fishes, which possess well-ossified trunk vertebræ, no distinct centra are developed at the extremity of the caudal region, and the notochord, invested in a more or less thickened, fibrous, or cartilaginous sheath, persists. Notwithstanding this embryonic condition of the axis of the tail, the superior and inferior arches, and the interspinous bones, may be completely formed in cartilage or bone.

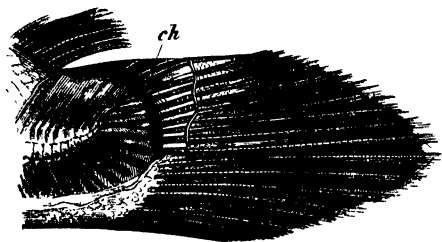
Whatever the condition of the extreme end of the spine of a fish, it occasionally retains the same direction as the trunk part, but is far more generally bent up, so as to form an obtuse angle with the latter. In the former case, the extremity of the spine divides the caudal fin-rays into two nearly equal moieties, an upper and a lower, and the fish is said to be *diphycercal* (Fig. 6, A). In the latter case, the upper division of the caudal fin-rays is much smaller than the lower, and the fish is *heterocercal* (Fig. 6, B, C).

In most osseous fishes the *hypural* bones which support the fin-rays of the inferior division become much expanded, and either remain separate, or coalesce into a wedge-shaped, nearly symmetrical bone, which becomes ankylosed with the last ossified vertebral centrum. The inferior fin-

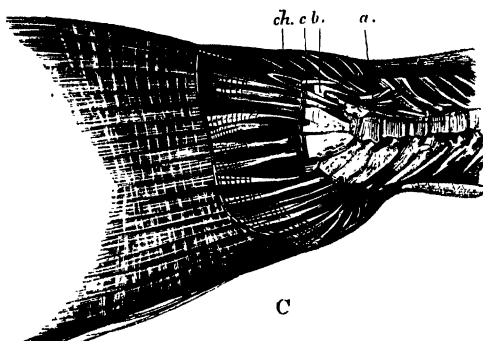
Fig. 6.



A



B



C

Fig. 6.—The caudal extremities of *Polypterus* (A), *Amia* (B), and *Salmo* (C). *Polypterus* is nearly diphy-cercal, the extremity of the notochord (*ch*) being hardly at all bent up. *Amia* is extremely heterocercal, but the hypural bones are hardly modified, and the notochord is invested only by cartilage. *Salmo*, finally, is strongly heterocercal, with expanded hypural bones, and a persistent notochord covered by the osseous plates *a*, *b*, and *c*.

rays are now disposed in such a manner as to give the tail an appearance of symmetry with respect to the axis of the body, and such fishes have been called *homocercal*. Of these homocercal fish, some (as the Salmon, Fig. 6) have the notochord unossified, and protected only by bony plates developed at its sides. In others (as the Stickleback, Perch, &c.), the sheath of the notochord becomes completely ossified and united with the centrum of the last vertebra, which then appears to be prolonged into a bony *urostyle*.

The Cranial System.—As has been stated, no protovertebræ appear on the floor of the skull; nor is there any

Fig. 7.

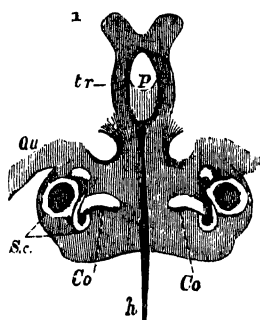


Fig. 7.—The cartilaginous cranium of a Fowl at the sixth day of incubation, viewed from below.—*P*, the pituitary space; *tr*, the *trabeculae*, uniting in front, in the bifurcated ethmovomerine plate; *Qu*, the quadrate cartilage; *Sc*, the semicircular canals; *Co*, the cochlea; *h*, the notochord imbedded in the basilar plate.

cranium, nor any developmental stage of a cranium, in which separate cartilaginous centres are known to occur in this region.

On the contrary, when chondrification takes place, it extends continuously forward, on each side of the notochord, and usually invests the anterior termination of that body, more or less completely, as a *basilar* plate.

The basilar plate does not extend under the floor of the pituitary fossa, but the cartilage is continued forwards on each side of this, in the form of two bars, the *trabeculae cranii*. In front of the fossa, the trabeculae reunite and end in a broad plate, usually bifurcated in the middle line—the *ethmovomerine* plate.

On each side of the posterior boundary of the skull, the basilar cartilage grows upwards, and meets with its fellow in the middle line, thus circumscribing the *occipital foramen*, and furnishing the only cartilaginous part of the roof of the skull; for any cartilaginous upgrowths which may be developed in the more anterior parts of the skull do not ordinarily reach its roof, but leave a wide, merely membranous space, or *fontanelle*, over the greater part of the brain.

Before the skull has attained this condition, the organs of the three higher senses have made their appearance in pairs at its sides; the *olfactory* being most anterior, the *ocular* next, the *auditory* posterior (Fig. 4).

Each of these organs is, primitively, an involution, or sac, of the integument; and each acquires a particular skeleton, which, in the case of the nose, is furnished by the ethmovomerine part of the skull; while, in that of the eyes, it appertains to the organ, is fibrous, cartilaginous, or osseous, and remains distinct from the skull. In the case of the ear, it is cartilaginous, and eventually osseous: whether primitively distinct or not, it early forms one mass with the skull, immediately in front of the occipital arch, and often constitutes a very important part of the walls of the fully-formed cranium.

The ethmovomerine cartilages spread over the nasal sacs, roof them in, cover them externally, and send down a partition between them. The partition is the proper *ethmoid*, the *lamina perpendicularis* of human anatomy; the posterolateral parts of the ethmovomerine cartilages, on each side of the partition, occupy the situation of the *pre-frontals*, or *lateral masses of the ethmoid* of human anatomy. The ingrowths of the lateral walls, by which the nasal

mucous membrane acquires a larger surface, are the *turbinals*.

Riblike cartilaginous rods appear in the first, second, and, more or fewer, of the succeeding, visceral arches in all but the lowest *Vertebrata*. The upper ends of the first and second of these become connected with the auditory capsule, which lies immediately above them.

The first visceral arch bounds the cavity of the mouth behind, and marks the position of the *mandible* or lower jaw. The cartilage which it contains is termed *Meckel's cartilage*.

The cartilaginous rod contained in the second visceral arch of each side is the rudiment of the *hyoidean* apparatus.

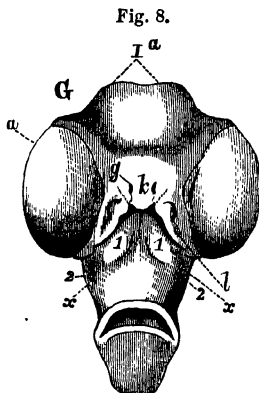


Fig. 8.—Under-view of the head of a Fowl at the seventh day of incubation.—*Ia*, the cerebral hemispheres causing the integument to bulge; *a*, the eyes; *g*, the olfactory sacs; *h*, the fronto-nasal process; *l*, the maxillary process; 1, 2, the first and second visceral arches; *x*, the remains of the first visceral cleft.

Like the preceding, it unites with its fellow in the ventral median line, where the so-called “body” of the hyoid arises.

A ridge, continued forward from the first visceral arch to the olfactory sac (Fig. 4, F; Fig. 8, *l*), bounds the mouth on each side, and is called the *maxillary process*. A cartilaginous *palato-pterygoid* rod, developed in this process,

becomes connected with Meckel's cartilage behind, and with the prefrontal cartilage in front.

The maxillary process is, at first, separated by a notch corresponding with each nasal sac, from the boundary of the antero-median part of the mouth, which is formed by the free posterior edge of a *fronto-nasal process* (Fig. 4, F; Fig. 8, *k*). This separates the nasal sacs, and contains the cartilaginous, ethmovomerine, anterior termination of the skull. The notch is eventually obliterated by the union of the fronto-nasal and maxillary processes, externally; but it may remain open internally, and then gives rise to the *posterior nasal aperture*, by which the nasal cavity is placed in communication with that of the mouth.

The General Modifications of the Vertebrate Skull.—The lowest vertebrated animal, *Amphioxus*, has no skull. In a great many fishes the development of the skull carries it no further than to a condition which is substantially similar to one of the embryonic stages now described; that is to say, there is a cartilaginous *primordial cranium*, with or without superficial granular ossifications, but devoid of any proper cranial bones. The facial apparatus is either incompletely developed, as in the Lamprey; or, the upper jaw is represented, on each side, by a cartilage answering to the palato-pterygoid and part of Meckel's cartilage, while the larger, distal portion of that cartilage becomes articulated with the rest, and forms the lower jaw. This condition is observable in the Sharks and Rays. In other fishes, and in all the higher *Vertebrata*, the cartilaginous cranium and facial arches may persist to a greater or less extent; but bones are added to them, which may be almost wholly membrane bones, as in the Sturgeon; or may be the result of the ossification of the cartilaginous cranium itself, from definite centres, as well as of the development of superimposed membrane bones.

The Osseous Brain-case.—When the skull undergoes complete ossification, osseous matter is thrown down at not fewer than three points in the middle of its cartilaginous

floor. The ossific deposit, nearest the occipital foramen becomes the *basi-occipital* bone; that which takes place in the floor of the pituitary fossa becomes the *basisphenoid* that which appears in the reunited trabeculæ, in front of the fossa, gives rise to the *presphenoid*. Again, in front of, and outside, the cranial cavity, the *ethmoid* may be represented by one or more distinct ossifications.

An ossific centre may appear in the cartilage on each side of the occipital foramen, and give rise to the *ex-occipital*; and above it, to form the *supra-occipital*. The four occipital elements, uniting together more or less closely, compose the *occipital segment* of the skull.

In front of the auditory capsules and of the exit of the third division of the fifth nerve, a centre of ossification may appear on each side and give rise to the *alisphenoid*; which, normally, becomes united below with the *basisphenoid*.

In front of, or above, the exits of the optic nerves, the *orbitosphenoidal* ossifications may appear and unite below with the *presphenoid*.

In front of the occipital segment, the roof of the skull is formed by membrane; and the bones which complete the two segments of which the *basisphenoid* and *presphenoid* form the basal parts, are membrane bones, and are disposed in two pairs. The posterior are the *parietals*, the anterior the *frontals*; and the segments which they complete are respectively called *parietal* and *frontal*. Thus the walls of the cranial cavity in the typical ossified skull are divisible into three segments—I. **Occipital**, II. **Parietal**, III. **Frontal**—the parts of which are arranged with reference to one another, the sensory organs and the exits of the first, second, fifth, and tenth pairs of cranial nerves (I., II., V., and X.), in the manner shown in the annexed diagram * :—

* The names of the purely membrane bones in this diagram are in large capitals, as **PARIETAL**; while those of the bones

which are preformed in cartilage are in smaller type, as **BASISPHE-NOID**.

The cartilaginous cases of the organs of hearing, or the *periotic capsules*, are, as has been said, incorporated with the skull between the ex-occipitals and the alisphenoids—or, in other words, between the occipital and the parietal segments of the skull. Each of them may have three principal ossifications of its own. The one in front is the *pro-otic*; the one behind and below, the *opisthotic*; and the one which lies above, and externally, the *epiotic*. The last is in especial relation with the posterior vertical semicircular canal; the first with the anterior vertical semicircular canal, between which, and the exit of the third division of the fifth nerve, it lies. These three ossifications may coalesce into one, as when they constitute the *petrosal* and *mastoid* parts of the temporal bone of human anatomy; or the *epiotic*, or the *opisthotic*, or both, may coalesce with the adjacent supra-occipital and ex-occipitals, leaving the *pro-otic* distinct. The *pro-otic* is, in fact, one of the most constant bones of the skull in the lower *Vertebrata*, though it is commonly mistaken, on the one hand for the alisphenoid, and on the other for the entire petro-mastoid. Sometimes a fourth, *pteric* ossification, is added to the three already mentioned. It lies on the upper and outer part of the ear-capsule between the *pro-otic* and the *epiotic* (see the figure of the cartilaginous cranium of the Pike, *infra*).

In some *Vertebrata* the base of the skull exhibits a long and distinct splint-like membrane bone*—the *parasphenoid*, which underlies it from the basi-occipital to the pre-

* Bones may be formed in two ways. They may be preceded by cartilage, and the ossific deposit in the place of the future bone may at first be deposited in the matrix of that cartilage; or the ossific deposit may take place, from the first, in indifferent, or rudimentary connective, tissue. In this case the bone is not prefigured by cartilage. In the skulls of Elasmobranch fishes, and in the sternum and epicoracoid of

Lizards, the bony matter is simply ossified cartilage, or cartilage bone. The parietal or frontal bones, on the other hand, are always devoid of cartilaginous rudiments, or, in other words, are *membrane bones*.

In the higher *Vertebrata* the cartilage bones rarely, if ever, remain as such; but the primitive ossified cartilage becomes, in great measure, absorbed and replaced by a membrane bone, derived from the perichondrium.

phenoidal region. In ordinary fishes and *Amphibia*, this bone appears to replace the basisphenoid and presphenoid functionally, while in the higher *Vertebrata* it becomes confounded with the basisphenoid. The *Vomer* is a similar, splint-like, single or double, membrane bone, which, in like manner, underlies the ethmoid region of the skull.

In addition to the bones already mentioned, a *prefrontal* bone may be developed in the prefrontal region of the nasal capsule, and bound the exit of the olfactory nerve externally.

A *postfrontal* bone may appear behind the orbit above the alisphenoid. Sometimes it seems to be a mere dismemberment of that bone; but, in most cases, the bone so named is a distinct membrane bone.

Furthermore, on the outer and upper surface of the auditory capsule a membrane bone, the *squamosal*, is very commonly developed; and another pair of splint-bones, the *nasals*, cover the upper part of the ethmovomerine chambers, in which the olfactory organs are lodged.

The Osseous Facial Apparatus.—The bones of the face, which constitute the inferior arches of the skull, appear within the various processes and visceral arches which have been enumerated. Thus, the *premaxillæ* are two bones developed in the oral part of the naso-frontal process, one on each side of the middle line, between the external nasal apertures, or *anterior nares*, and the anterior boundary of the mouth.

Ossification occurs in the palato-pterygoid cartilage at two chief points, one in front and one behind. The anterior gives rise to the *palatine* bone, the posterior to the *pterygoid*. Outside these, several membrane bones may make their appearance in the same process. The chief of these is the *maxilla*, which commonly unites, in front, with the premaxilla. Behind the maxilla there may be a second, the *jugal*; and occasionally behind this lies a third, the *quadrato-jugal*.

Between the maxilla, the prefrontal, and the premaxilla, another membrane bone, called *lachrymal*, from its ordinary

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Between the maxilla, the prefrontal, and the premaxilla, another membrane bone, called *lachrymal*, from its ordinary

relation to the lachrymal canal, is very generally developed; and one or more *supra-orbital* and *post-orbital* ossifications may be connected with the bony boundaries of the orbit.

When these and the postfrontal membrane bone are simultaneously developed, they form two series of bony splints attached to the lateral wall of the skull, one set above and one below the orbit, which converge to the lachrymal. The upper series (lachrymal, supra-orbital, post-frontal, squamosal), terminates posteriorly over the proximal end of the *quadrate bone*, or *mandibular suspensorium*. The lower series (lachrymal, maxillary, jugal, quadrato-jugal) ends over the distal end of that bone, with which the quadrato-jugal is connected. The two series are connected behind the orbit by the post-orbital (when it exists), but more commonly by the union of the jugal with the post-frontal and squamosal. The *Ichthyosauria*, *Chelonia*, *Crocodylia*, and some *Lacertilia*, exhibit this double series of bones most completely.

Each nasal passage, at first very short, passes between the premaxilla below, the ethmoid and vomer on the inner side, the prefrontal above and externally, and the palatine behind, to open into the fore part of the mouth. And, before the cleft between the outer posterior angle of the naso-frontal process and the maxillary process is closed, this passage communicates, laterally, with the exterior, and, posteriorly, with the cavity of the orbit. When the maxillary and the naso-frontal processes unite, the direct external communication ceases; but the orbito-nasal passage, or *lachrymal canal*, as it is called, in consequence of its function of conveying away the secretion of the lachrymal gland, may persist, and the *lachrymal bone* may be developed in especial relation with it.

In the higher *Vertebrata*, the nasal passages no longer communicate with the fore part of the cavity of the mouth; for the maxillaries and palatines, regularly, and the pterygoid bones, occasionally, send processes downwards and inwards, which meet in the middle line, and shut off from the mouth

a canal which receives the nasal passages in front, while it opens, behind, into the pharynx, by what are now the *posterior nares*.

Two ossifications commonly appear near the proximal end of Meckel's cartilage, and become bones moveably articulated together. The proximal of these is the *quadrate* bone found in most vertebrates, the *malleus* of mammals; the distal is the *os articulare* of the lower jaw in most vertebrates, but

Fig. 9.

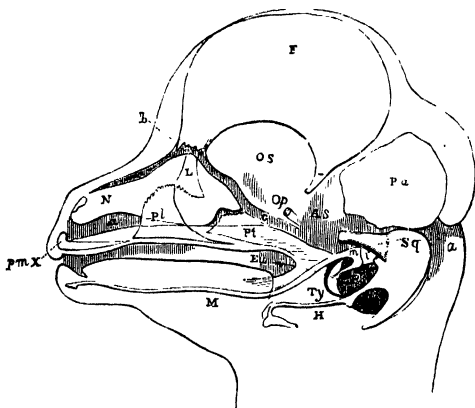


Fig. 9.—The head of a foetal Lamb dissected so as to show Meckel's cartilage, *M*; the malleus, *m*; the incus, *i*; the tympanic, *Ty*; the hyoid, *H*; the squamosal, *Sq*; pterygoid, *Pt*; palatine, *pl*; lachrymal, *L*; premaxilla, *pmx*; nasal sac, *N*; Eustachian tube, *Eu*.

does not seem to be represented in mammals. The remainder of Meckel's cartilage usually persists for a longer or shorter time, but does not ossify. It becomes surrounded by bone, arising from one or several centres in the adjacent membrane, and the *ramus of the mandible* thus formed, articulates with the squamosal bone in mammals, but in other *Vertebrata* is immoveably united with the *os articulare*. Hence the complete ramus of the mandible articulates

directly with the skull in mammals, but only indirectly, or through the intermediation of the quadrate, in other *Vertebrata*. In birds and reptiles, the proximal end of the quadrate bone, articulates directly (with a merely apparent exception in *Ophidia*), and independently of the hyoidean apparatus, with the periotic capsule. In most, if not all fishes, the connection of the mandibular arch with the skull is effected indirectly, by its attachment to a single cartilage or bone, the *hyomandibular*, which represents the proximal end of the hyoidean arch (see Fig. 24).

The ossification of the hyoidean apparatus varies immensely in detail, but usually gives rise to bony lateral arches, and a median portion, bearing much the same relation to them as the sternum has to the ribs. When the lateral arches are complete they are connected directly with the periotic capsule.

The proximal end of the hyoidean arch is often united, more or less closely, with the outer extremity of the bone, called *columella auris*, or *stapes*, the inner end of which, in the higher *Vertebrata*, is attached to the membrane of the *fenestra ovalis*.

In ordinary fishes, a fold of the integument extends backwards from the second visceral arch over the persistent branchial clefts; within this is developed a series of raylike membrane bones, termed *opercular* and *branchiostegal*, which become closely connected with the hyoidean arch. A corresponding process of the skin is developed in the Batrachian Tadpole, and grows backwards over the branchiæ. Its posterior edge, at first free, eventually unites with the integument of the body, behind the branchial clefts, the union being completed much earlier on the right side, than on the left.

In most mammals a similar fold of integument gives rise to the *pinna*, or external ear.

The *branchial* skeleton bears the same relation to the posterior visceral arches that the hyoidean does to the second. When fully developed, it exhibits ossified lateral arches, connected by median pieces, and, frequently, pro-

vided with radiating appendages which give support to the branchial mucous membrane. It is only found in those *Vertebrata* which breathe by gills—the classes *Pisces* and

Fig 10.

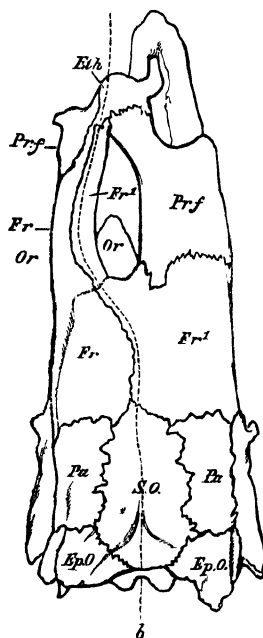


Fig. 10.—The skull of a Plaice (*Platessa vulgaris*), viewed from above. The dotted line *a, b*, is the true morphological median line; *Or*, the position of the two eyes in their orbits; *Eth*, ethmoid; *Prf*, prefrontal; *Fr*, left frontal; *Fr1*, right frontal; *Pa*, parietal; *SO*, supra-occipital; *Ep.O*, epiotic.

Amphibia. In the higher *Vertebrata*, the posterior of the two pairs of cornua with which the hyoidean apparatus is generally provided, are the only remains of the branchial skeleton.

The skull and face are usually symmetrical in reference to a median vertical plane. But, in some *Cetacea*, the bones about the region of the nose are unequally developed, and the skull becomes asymmetrical. In the Flatfishes (*Pleuronectidæ*), the skull becomes so completely distorted that the two eyes lie on one side of the body, which is, in some cases, the left, and, in others, the right side. In certain of these fishes, the rest of the skull and facial bones, the spine, and even the limbs, partake in this asymmetry. The base of the skull and its occipital region are comparatively little affected; but, in the interorbital region, the frontal bones and the subjacent cartilaginous, or membranous, side-walls of the cranium are thrown over to one side; and, frequently, undergo a flexure, so that they become convex towards that side, and concave in the opposite direction. The prefrontal bone of the side from which the skull is twisted sends back a great process above the eye of that side, which unites with the frontal bone, and thus incloses this eye in a complete bony orbit. It is along this fronto-prefrontal bridge that the dorsal fin-rays are continued forwards, just as if this bridge represented the morphological middle of the skull. (Fig. 10.)

The embryonic *Pleuronectidæ* have the eyes in their normal places, upon opposite sides of the head; and the cranial distortion commences only after the fish are hatched.

The Appendicular Endoskeleton.—The limbs of all vertebrated animals make their appearance as buds on each side of the body. In all but fishes, these buds become divided by constrictions into three segments. Of these, the proximal is called *brachium* in the fore-limbs, *femur* in the hind; the middle is *antebrachium*, or *crus*; the distal is *manus*, or *pes*. Each of these divisions has its proper skeleton, composed of cartilage and bone. The proximal division, normally, contains only one bone, *os humeri*, or *humerus*, in the brachium—and *os femoris*, or *femur*, in the thigh; the middle, two bones, side by side, *radius* and *ulna*, or *tibia* and *fibula*; the distal, many bones, so disposed as to form not more than five longitudinal series, except in the

Ichthyosauria, where marginal bones are added, and some of the digits bifurcate.

The skeletal elements of the manus and pes are divisible into a proximal set, constituting the *carpus* or *tarsus*; and a distal set, the *digits*, of which there are normally five, articulated with the distal bones of the carpus and tarsus. Each digit has a proximal *basi-digital* (*metacarpal*, or *metatarsal*) bone, upon which follows a linear series of *phalanges*. It is convenient always to count the digits in the same way, commencing from the radial or tibial side. Thus, the thumb is the first digit of the hand in man; and the great toe the first digit of the foot. Adopting this system, the digits may be represented by the numbers i, ii, iii, iv, v.

There is reason to believe that, when least modified, the carpus and the tarsus are composed of skeletal elements which are alike in number and in arrangement. One of these, primitively situated in the centre of the carpus or tarsus, is termed the *centrale*; on the distal side of this are five *carpalia*, or *tarsalia*, which articulate with the several metacarpal or metatarsal bones; while, on its proximal side, are three bones—one *radiale* or *tibiale*, articulating with the radius or tibia; one *ulnare* or *fibulare*, with the ulna or fibula; and one *intermedium*, situated between the foregoing. Carpal and tarsal bones, or cartilages, thus disposed are to be met with in some *Amphibia* and *Chelonia* (Fig. 11), but, commonly, the typical arrangement is disturbed by the suppression of some of these elements, or their coalescence with one another. Thus, in the carpus of man, the *radiale*, *intermedium*, and *ulnare* are represented by the *scaphoides*, *lunare*, and *cuneiforme* respectively. The *pisiforme* is a sesamoid bone developed in the tendon of the *flexor carpi ulnaris*, which has nothing to do with the primitive carpus. The *centrale* is not represented in a distinct shape, having probably coalesced with one of the other elements of the carpus. The fourth and fifth *carpalia* have coalesced, and form the single *unciforme*. In the tarsus of man the *astragalus* represents the coalesced *tibiale* and *intermedium*; the *calcaneum*, the *fibulare*. The *naviculare* is the *centrale*. Like

the corresponding bones in the carpus, the fourth and fifth tarsalia have coalesced to form the *cuboides*.

Fig. 11.

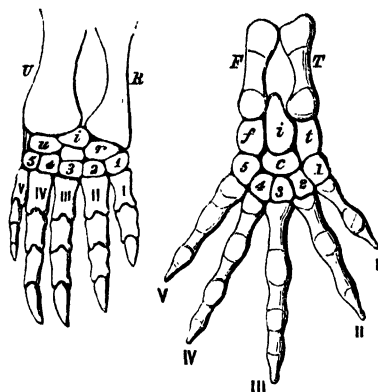


Fig. 11.—The right forefoot of the Chelonian *Chelydra*, and the right hind-foot of the Amphibian *Salamandra*.—*U.* ulna; *R.* radius; *F.* fibula; *T.* tibia.

Proximal carpal bones: *r.* radiale; *i.* intermedium; *u.* ulnare; the centrale is the middle unlettered bone.

Proximal tarsal bones: *t.* tibiale; *i.* intermedium; *f.* fibulare; *c.* centrale; 1, 2, 3, 4, 5, distal carpalia and tarsalia; I, II, III, IV, V, digits.

The Position of the Limbs.—In their primitive position, the limbs are straight, and are directed outwards, at right angles to the axis of the body; but, as development proceeds, they become bent in such a manner that, in the first place, the middle division of each limb is flexed downwards and towards the middle line, upon the proximal division; while the distal division takes an opposite bend upon the middle division. Thus the ventral aspects of the *antebrachium* and *crus* come to look inwardly, and the dorsal aspects outwardly; while the ventral aspects of the *manus* and *pes* look downwards, and their dorsal aspects look upwards. When the position of the limbs has been no further

altered than this, the radius in the antebrachium, and the tibia in the crus, are turned forwards, or towards the head; the ulna and the fibula backwards, or towards the caudal extremity. On looking at these parts with respect to the axis of the limb itself, the radius and the tibia are *pre-axial*, or in front of the axis; while the ulna and fibula are *post-axial*, or behind it. The same axis traverses the centre of the middle digit, and there are therefore two pre-axial, or radial, or tibial digits; and two post-axial, or ulnar, or fibular digits, in each limb. The most anterior of the digits (i) is called *pollex*, in the manus; and *hallux*, in the pes. The second digit (ii) is the *index*; the third (iii) the *medius*; the fourth (iv) the *annularis*; and the fifth (v) the *minimus*.

In many *Amphibia* and *Reptilia*, the limbs of the adult do not greatly depart from this primitive position; but in birds and in mammals, further changes occur. Thus, in all ordinary quadrupeds, the brachium is turned backwards and the thigh forwards, so that both elbow and knee lie close to the sides of the body. At the same time, the forearm is flexed upon the arm, and the leg upon the thigh. In Man a still greater change occurs. In the natural erect posture, the axes of both arm and leg are parallel with that of the body, instead of being perpendicular to it. The proper ventral surface of the brachium looks forwards, and that of the thigh backwards, while the dorsal surface of the latter looks forwards. The dorsal surface of the antebrachium looks outwards and backwards. that of the leg directly forwards. The dorsal surface of the manus is external, that of the pes, superior. Thus, speaking broadly, the back of the arm corresponds with the front of the leg, and the outer side of the leg with the inner side of the arm, in the erect position.

In Bats, a line drawn from the acetabulum to the foot is also, in the natural position, nearly parallel with the long axis of the body. But, in attaining this position, the leg is bent at the knee and turned backwards; the proper dorsal surface of the thigh looking upwards and forwards.

while the corresponding surface of the leg looks backwards and upwards, and the unguis phalanges are turned backwards.

The chief modifications of the manus and pes arise from the excess, or defect, in the development of particular digits, and from the manner in which the digits are connected with one another, and with the carpus or tarsus. In the *Ichthyosauria* and *Plesiosauria*, the Turtles, the *Cetacea* and *Sirenia*, and, in a less degree, in the Seals, the digits are bound together and cased in a common sheath of integument, so as to form *paddles*, in which the several digits have little or no motion on one another.

The fourth digit of the manus in the *Pterosauria*, and the four ulnar digits in the Bats, are vastly elongated, to support the web which enables these animals to fly. In existing birds the two ulnar, or post-axial, digits are aborted, the metacarpals of the second and third are ankylosed together, and the digits themselves are inclosed in a common integumentary sheath; the third invariably, and the second usually, is devoid of a claw. The metacarpal of the pollex is ankylosed with the others, but the rest of that digit is free, and frequently provided with a claw.

Among terrestrial mammals, the most striking changes of the manus and pes arise from the gradual reduction in the number of the perfect digits from the normal number of five to four (*Sus*), three (*Rhinoceros*), two (most *Ruminantia*), or one (*Equidæ*).

The Pectoral and Pelvic Arches.—The proximal skeletal elements of each pair of limbs (*humeri* or *femora*) are supported by a primitively cartilaginous, *pectoral*, or *pelvic* girdle, which lies external to the costal elements of the vertebral skeleton. This girdle may consist of a simple cartilaginous arc (as in the Sharks and Rays), or it may be complicated by subdivisions and additions.

The pectoral arch may be connected with the skull, or with the vertebral column, by muscles, ligaments, or dermal ossifications, though, primitively, it is perfectly free from

and independent of, both; but it is never united with the vertebræ by the intermediation of ribs. At first, it consists of one continuous cartilage, on each side of the body, distinguishable only into regions and processes, and affording an articular surface to the bones, or cartilages, of the limb. But ossification usually sets up in the cartilage, in such a way, as to give rise to a dorsal bone, called the *scapula*, or shoulderblade, which meets, in the articular, *glenoidal* cavity for the humerus, with a ventral ossification, termed the *coracoid*.

By differences in the mode of ossification of the various parts, and by other changes, that region of the primitively

Fig. 12.

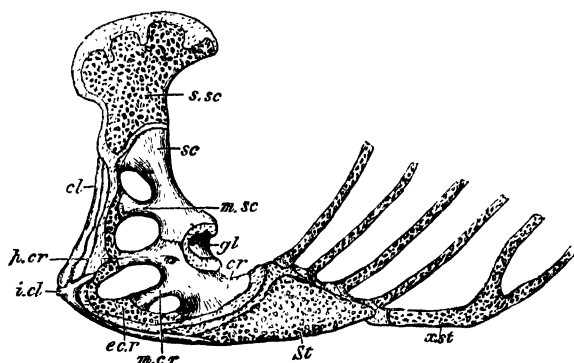


Fig. 12.—Side-view of the pectoral arch and sternum of a Lizard (*Iguana tuberculata*).—Sc, scapula; s.sc, supra-scapula; cr, coracoid; gl, glenoidal cavity; St, sternum; x.st, xiphisternum; m.sc, mesoscapula; p.cr, precoracoid; m.cr, mesocoracoid; e.cr, epicoracoid; cl, clavicle; i.cl, interclavicle.

cartilaginous pectoral arch, which lies above the glenoidal cavity, may be ultimately divided into a *scapula* and a *supra-scapula*; while that which lies on the ventral side may present not only a *coracoid*, but a *precoracoid* and an *epicoracoid*.

In the great majority of the *Vertebrata* above fishes, the

coracoids are large, and articulate with the antero-external margins of the primitively cartilaginous *sternum*, or breast-bone. But, in most mammals, they do not reach the sternum, and, becoming ankylosed with the scapula, they appear, in adult life, as mere processes of that bone.

Numerous Vertebrates possess a *clavicula*, or collar-bone, which is connected with the pre-axial margin of the *scapula* and *coracoid*, but takes no part in the formation of the

Fig. 13.

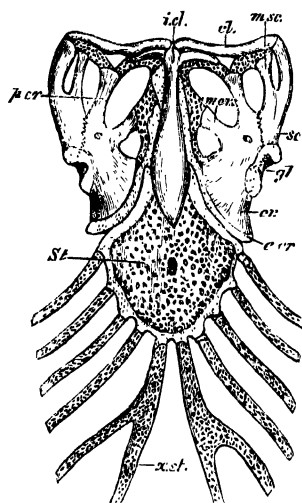


Fig. 13.—Ventral view of the sternum and pectoral arches of *Iguana tuberculata*. The letters as in Fig. 12.

glenoid cavity, and is usually, if not always, a membrane bone. In many *Vertebrata*, the inner ends of the clavicles are connected with, and supported by, a median membrane bone which is closely connected with the ventral face of the sternum. This is the *interclavicula*, frequently called *episternum*.

The pelvic, like the pectoral, arch at first consists of a simple continuous cartilage on each side, which, in *Vertebrata* higher than fishes, is divided by the *acetabulum*, or articular cavity for the reception of the head of the femur, into a dorsal and a ventral moiety.

Three separate ossifications usually take place in this cartilage—one in the dorsal, and two in the ventral, moiety. Hence, the pelvic arch eventually consists of a dorsal portion, called the *ilium*, and of two ventral elements, the *pubis* anteriorly, and the *ischium* posteriorly. All these generally enter into the composition of the acetabulum.

The ilium corresponds with the scapula. In the higher *Vertebrata* the outer surface of the latter bone becomes

Fig. 14.

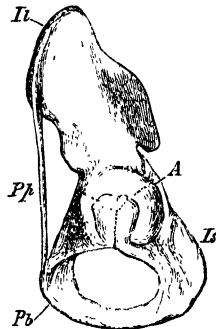


Fig. 14.—Side-view of the left Os innominatum of Man: *Il*, ilium; *Is*, ischium; *Pb*, pubis; *A*, acetabulum; *Pp*, Poupart's ligament.

divided by a ridge into two fossæ. The ridge, called the *spine of the scapula*, frequently ends in a prominent process termed the *acromion*, and with this, in *Mammalia*, the clavicle articulates. In like manner, the outer surface of the ilium becomes divided by a ridge which grows out into a great crest in Man and other *Mammalia*, and gives attachment to muscles and ligaments.

The ischium corresponds very nearly with the coracoid

in the pectoral arch; the pubis with the precoracoid, and more or less of the epicoracoid.

The pelvis possesses no osseous element corresponding with the clavicle, but a strong ligament, the so-called *Poupart's ligament*, stretches from the ilium to the pubis in many *Vertebrata*, and takes its place. (Fig. 14, *Pp.*)

On the other hand, the *marsupial bones* of certain mammals, which are ossifications of the tendons of the external oblique muscles, seem to be unrepresented in the pectoral arch; while there appears to be nothing clearly corresponding with a sternum in the pelvic arch, though the *preloacal cartilage*, or *ossicle*, of Lizards has much the same relation to the ischia as the sternum has to the coracoids.

Very generally, though not universally, the ilia are closely articulated with the modified ribs of the sacrum. The pubes and ischia of opposite sides usually meet in a median ventral symphysis; but in all birds, except the Ostrich, this union does not take place.

The Limbs of Fishes.—The limbs of Fishes have an endoskeleton which only imperfectly corresponds with that of the higher Vertebrates. For while homologues of the cartilaginous, and even of the bony, constituents of the pectoral and pelvic arches of the latter are traceable in Fishes, the cartilaginous, or ossified, basal and radial supports of the fins themselves cannot be identified, unless in the most general way, with the limb-bones, or cartilages, of the other *Vertebrata*.

In its least modified form, as in *Lepidosiren*, the endoskeleton of the fish's fin is a simple cartilaginous rod, divided into many joints; and articulated, by its proximal end, with the pectoral arch. The *Elasmobranchii* possess three basal cartilages which articulate with the pectoral arch, and are called, respectively, from before backwards—*propterygial*, *mesopterygial*, and *metapterygial basalia*. With these are articulated linear series of *radial* cartilages, upon which osseous, or horny, dermal fin-rays are superimposed. (Fig. 15.)

Among the Ganoid fishes, the fins of *Polypterus* are, fundamentally, like those of the *Elasmobranchii*; but the propterygial, mesopterygial, and metapterygial *basalia*, are more or less ossified, and are succeeded by a series of elongated *radialia*, which are also, for the most part, ossified. Beyond these follow some small additional *radialia*, which

Fig. 15.

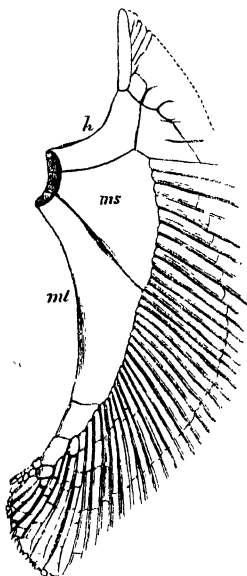


Fig. 15.—The right pectoral member of the Monkfish (*Squatina*): *h*, propterygium; *ms*, mesopterygium; *mt*, metapterygium.

remain cartilaginous, and are embraced by the bases of the fin-rays. In the other Ganoids the propterygial basale disappears, and some of the radialia, pushing themselves between the mesopterygial and metapterygial basalia, articulate directly with the pectoral arch. The mesopterygial

basale is embraced by, and becomes more or less incorporated with, the large anterior fin-ray.

From these Ganoids the passage is easy to the *Teleostei*, in which, also, the mesopterygial basale always becomes fused with the anterior fin-ray, whence the latter seems to articulate directly with the shoulder-girdle. Four bones, of very similar general form, usually articulate with the pectoral arch, beneath and behind the mesopterygial basale and its fin-ray. At their distal ends small cartilaginous nodules may lie, and these are embraced by the fin-rays. Of these four bones, or partially ossified cartilages, the lowermost and hindermost answers to the metapterygial basale of the Shark; the others seem to be *radialia*. (See the figure of the Pike's pectoral fin, *infra*.)

The ventral fins have basal and radial cartilages and fin-rays, more or less resembling those of the fore limbs.

In most Ganoids and Teleosteans the pectoral and pelvic arches are, in part, or completely, ossified; the former frequently presenting distinct scapular and coracoid bones. To these, in all Ganoids and Teleosteans, membrane bones, representing a clavicle, with *supra-clavicular* and *post-clavicular* ossifications, are added.

In all Elasmobranchs and Ganoids, and in a large proportion of the Teleosteans, the pelvic fins are situated far back on the underside of the body, and are said to be "ventral" in position; but, in other Teleosteans, the ventral fins may move forward, so as to be placed immediately behind, or even in front of, the pectoral fins. In the former case they are said to be "thoracic," in the latter "jugular."

The Vertebrate Exoskeleton.—The *Exoskeleton* never attains, in vertebrated animals, the functional importance which it so frequently possesses among the *Invertebrata*, and it varies very greatly in the degree of its development.

The *integument* consists of two layers—a superficial, non-vascular substance, the *epidermis*, composed of cells, which are constantly growing and multiplying in the deeper, and being thrown off in the superficial, layers; and a deep vascular tissue, the *dermis*, composed of more or less

completely-formed connective tissue. An exoskeleton may be developed by the hardening of either the epidermis, or the dermis.

The *epidermal exoskeleton* results from the conversion into horny matter of the superficial cells of the epidermis. The horny plates thus formed are moulded upon, and follow the configuration of, *areae*, or processes, of the dermis. When the latter are overlapping folds, the horny epidermic investment is called a scale, *squama*. When the dermic process is papilliform, and sunk in a pit of the dermis, the conical cap of modified epidermis which coats it, is either a *hair* or a *feather*. To become a hair, the horny cone simply elongates by continual addition of new cells to its base; but, in a feather, the horny cone, which also elongates by addition to its base, splits up, for a greater or less distance along the middle line of its under-surface, and then spreads out into a flat vane, subdivided into *barbs*, *barbules*, &c., by a further process of splitting of the primary horny cone.

The epidermis remains soft and delicate in Fishes and *Amphibia*. In *Reptilia* it sometimes takes the form of plates, which attain a great size in many *Chelonias*; sometimes, that of overlapping scales, as in *Ophidia* and many *Lacertilia*; but, sometimes, it remains soft, as in some *Chelonias* and in the *Chamæleons*. Epidermic plates in the form of *nails* appear upon the terminal phalanges of the limbs.

All *Aves* possess feathers. In addition, the beak is partly or completely ensheathed in horn, as in some *Reptilia*. Cornified epidermic tubercles, or plates, are developed on the tarsi and toes, the terminal phalanges of which (and sometimes those of the wing) have nails. Beside these, some birds possess spurs, which are ensheathed in horn, on the legs or wings.

In *Mammalia* the horny exoskeleton may take all the forms already mentioned, except that of feathers. In some *Cetacea* it is almost absent, being reduced to a few hairs, present only in the foetal state. The Pangolin (*Manis*), on the other hand, is almost completely covered with scales, the Armadillos with plates, and most terrestrial mammals

with a thick coat of hair. The greater part of the mass of the horns of Oxen, Sheep, and Antelopes, is due to the epidermic sheath which covers the bony core. Where the horny epidermis becomes very thick, as in the hoof of the Horse, and in the horn of the Rhinoceros, numerous long papillæ of the dermis extend into it. These papillæ, however, are comparable to the ridges of the bed of the nail, not to the papillæ of the hairs.

Fig. 16.

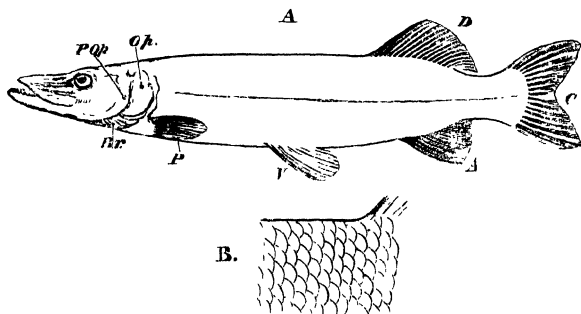


Fig. 16.—A, outline of a Pike (*Esox*), to show the fins: *P*, pectoral; *V*, ventral; *A*, anal; *C*, caudal; *D*, dorsal, fins. *Op.*, operculum; *P.Op.*, preoperculum; *Br.*, branchiostegal rays.—B, scales of the dermal exoskeleton of the same fish.

The *dermal exoskeleton* arises from the hardening of the dermis; in the majority of cases by the deposit of bone-earth, in more or less completely-formed connective tissue, though the resulting hard tissue has by no means always the structure of bone. It may happen that cartilage is developed in the dermis; and, either in its primary state, or ossified, gives rise to exoskeletal parts.

No dermal exoskeleton (except that of the fin-rays) is found in the lowest fishes, *Amphioxus* and the *Marsipobranchii*. In most *Teleostei* the integument is raised up into overlapping folds; and, in these, calcification takes

place in laminæ, of which the oldest is the most superficial, and lies immediately beneath the epidermis. As a general rule, the calcified tissue of the "scale" thus formed, does not possess the structure of true bone in the *Teleostei*. But in other fishes, the dermal calcification may consist of true bone (as in the Sturgeon); or, as in the Sharks and Rays, may take on the structure of teeth, and consist mainly of a tissue exactly comparable to dentine, capped with enamel, and continuous by its base with a mass of true bone, which takes the place of the *crusta petrosa*, or cement of the teeth.

A form of dermal exoskeleton, which is peculiar to and highly characteristic of fishes, is found in the *fin-rays*. These are developed in the integument either of the median line of the body, or in that of the limbs. In the former case, they usually enter into, or support, folds of the integument which are termed *dorsal*, *caudal*, or *anal* fins—according as they lie in the dorsal region, or at the extremity of the body, or on the ventral aspect, behind the anus. Ordinary fin-rays are composed of a hornlike, or more or less calcified, substance, and are simple at the base, but become jointed transversely, and split up longitudinally, towards their extremities (Fig. 6). Each fin-ray consists of two nearly equal and similar parts, which cohere by their applied faces for the greater part of their extent; but, at the base of the ray, the halves commonly diverge, to embrace, or more or less completely coalesce with, cartilaginous or osseous elements of the exoskeleton. In the median fins, these are the *interspinous* cartilages, or bones, which lie between the fin-rays and the superior or inferior spines of the vertebræ. In the paired fins, they are radial or basal, cartilaginous or osseous, elements of the endoskeleton.

The *Amphibia* in general are devoid of dermal exoskeleton, but the *Cæciliæ* have scales like those of fishes. *Ceratophrys* has plates of bone developed in the dorsal integument, which seem to foreshadow the plates of the carapace of the *Chelonia*; and the extinct Labyrinthodonts possessed a very remarkable ventral exoskeleton.

The *Ophidia* have no dermal exoskeleton. Many Lizards

have bony dermal plates corresponding in form and size with the epidermal scales. All *Crocodylia* have such bony plates in the dorsal region of the body and tail; and in some, such as the Jacares and Caimans, and the extinct *Teleosauria*, they are also developed in the ventral region. In these animals there is a certain correspondence between the segments of the exoskeleton and those of the endoskeleton. But the dermal exoskeleton attains its greatest development in the *Chelonina*, and will be particularly described under the head of that order.

In the *Mammalia* the development of a dermal exoskeleton is exceptional, and occurs only in the loricated *Edentata*, in which the dorsal region of the head and body, and the whole of the tail, may be covered with shields of dermal bone.

In connection with the dermis and epidermis, the glandular and pigmentary organs of the integument may be mentioned. Integumentary glands do not appear to exist in Fishes, but they attain an immense development in some of the *Amphibia*, as the Frog. Among *Reptilia*, Lizards frequently present such glands in the femoral and cloacal regions; and, in Crocodiles, integumentary glands, which secrete a musky substance, lie beneath the jaw. In Birds they attain a considerable size in the uropygial gland; and, in *Mammalia*, acquire a large development in connection with the sacs of the hairs, or as independent organs, in the form of sweat-glands, musk-glands, or mammary glands.

The colour of the integument may arise from pigment-granules, deposited either in the epidermis or in the dermis; and in the latter case, it is sometimes contained in distinct chromatophores, as in the *Chameleon*.

CHAPTER II.

THE MUSCLES AND THE VISCERA—A GENERAL VIEW OF
THE ORGANIZATION OF THE VERTEBRATA.

THE muscular system of the *Vertebrata* consists of muscles related partly to the exoskeleton, partly to the endoskeleton, and partly to the viscera, and formed both of striated and unstriated muscular fibre. The latter is confined to the vessels, the viscera, and the integument; the parts of the endoskeleton being moved upon one another exclusively by striated muscular fibre. The muscles of the endoskeleton may be divided, like the endoskeleton itself, into one system appertaining to the trunk and head, and another belonging to the limbs.

The Muscular System of the Trunk and Head.—This consists of two portions, which differ fundamentally in their origin, and in their relations to the endoskeleton. The one takes its origin in the protovertebræ; each protovertebra becoming differentiated, as we have seen, into three parts; a spinal ganglion and a segment of the vertebral endoskeleton, in the same plane, and a more superficial sheet of muscular fibres. These muscular fibres are consequently situated above the endoskeleton, or are *episkeletal*. Other muscular fibres are developed below the endoskeleton, and may be termed *hyposkeletal* muscles. The *hyposkeletal* muscles are separated from the *episkeletal*, not only by the endoskeleton of the trunk (or the vertebræ and their prolongations, the ribs), but by the ventral branches of the spinal nerves.

As the *episkeletal* muscles are developed out of the protovertebræ, they necessarily, at first, present as many seg-

ments as there are vertebræ, the interspaces between them appearing as *intermuscular septa*. The development of the hyposkeletal muscles has not been worked out, but it appears to take place much later than that of the episkeletal set.

In the lowest *Vertebrata*—as, for example, in ordinary fishes—the chief muscular system of the trunk consists of the episkeletal muscles, which form thick lateral masses of longitudinal fibres, divided by transverse intermuscular septa into segments (or *Myotomes*) corresponding with the vertebræ. The lateral muscles meet in the middle line below, and divide, in front, into a dorso-lateral mass connected with the skull, and a ventro-lateral attached, in part, to the pectoral arch, and, in part, continued forwards to the skull, to the hyoidean apparatus, and to the mandible. Posteriorly, the lateral muscles are continued to the extremity of the tail. The hyposkeletal muscular system appears to be undeveloped.

In the higher *Vertebrata*, both the episkeletal and hyposkeletal muscular systems are represented by considerable numbers of more or less distinct muscles. The dorso-lateral division of the lateral muscle of the fish is represented by the superior caudal muscles, and by the *erector spinæ*; which, as it splits up, anteriorly, and becomes attached to the vertebræ, and to the ribs, and to the skull, acquires the names of *spinalis*, *semispinalis*, *longissimus dorsi*, *sacro-lumbalis*, *inter-transversalis*, *levator costarum*, *complexus*, *splenius*, *recti postici*, and *recti laterales*.

The ventro-lateral division of the fish's lateral muscle is represented, in the middle line of the trunk and head, by a series of longitudinal muscles; and, at the sides, by obliquely-directed muscles. The former are the *recti abdominis*, extending from the pelvis to the sternum—the *sterno-hyoidei*, between the sternum and the hyoidean apparatus—the *genio-hyoidei*, which pass from the hyoid to the symphysis of the mandible. The latter are the *obliqui externi* of the abdomen—the external *intercostales* of the thorax—the *subclavius* stretching from the first rib to the clavicle; the *scaleni* from the anterior dorsal ribs to the cervical ribs and

transverse processes, and the *sterno-* and *cleido-mastoidei* from the sternum and clavicle to the skull.

The fibres of all these oblique muscles take a direction, from parts which are dorsal and anterior, to others which are ventral and posterior.

The trunk muscles of the lower *Amphibia* exhibit arrangements which are transitional between those observed in Fishes and that which has been described in Man, and which substantially obtains in all abbranchiate *Vertebrata*.

The muscles of the jaws and of the hyoidean apparatus appear to be, in part, episkeletal, and, in part, hyoskeletal. The mandible is depressed by a muscle, the *digastric*, arising from the skull, and supplied by a branch of the seventh nerve: it is raised by a muscular mass, which is separable into *masseter*, *temporal*, and *pterygoid* muscles, according to its connection with the maxillo-jugal bones, the sides of the skull, or the palato-pterygoid bones, and is supplied by the fifth nerve.

The proper facial muscles belong to the system of cutaneous muscles, and receive branches from the seventh nerve.

The hyoskeletal system is formed, partly, of longitudinal muscles which underlie the vertebral column; and partly, of more or less oblique, or even transverse fibres, which form the innermost muscular walls of the thorax and of the abdomen.

The former are the subcaudal intrinsic flexors of the tail; the *pyriformis*, *psoas*, and other muscles proceeding from the inferior faces of the vertebræ to the hind limb; the *longus colli*, or intrinsic flexor of the anterior part of the vertebral column; and the *recti capitis antici*, or flexors of the head upon the vertebral column. The latter are the *obliquus internus* of the abdomen, the fibres of which take a direction crossing that of the external oblique muscle; and the *transversalis*, which lies innermost of the abdominal muscles, and has its fibres transverse. In the thorax, the *intercostales interni* continue the direction of the internal oblique, and the *triangularis sterni* that of the *transversalis*. The *diaphragm* and the *levator ani* must also be enumerated among

the hyposkeletal muscles. The hyposkeletal muscles of the posterior moiety of the body attain a great development in those *Vertebrata* which have no hind limbs, such as *Ophidia* and *Cetacea*.

The Muscular System of the Limbs.—The muscles of the limbs of Fishes are very simple, consisting, on each face of the limb, of bundles of fibres, which proceed (usually in two layers) obliquely, from the clavicle and supraclavicle to the fin-rays. The pectoral and pelvic arches themselves are imbedded in the lateral muscles.

In the *Amphibia* and all the higher *Vertebrata*, the muscles of the limbs are divisible into—*intrinsic*, or those which take their origin within the anatomical limits of the limb (including the pectoral or pelvic arch); and *extrinsic*, or those which arise outside the limb.

Supposing the limb to be extended at right angles to the spine (its primitive position), it will present a *dorsal aspect* and a *ventral aspect*, with an anterior, or *pre-axial*, and a posterior, or *post-axial*, side.

In the *Vertebrata* above fishes, the following muscles, which occur in Man, are very generally represented :

Extrinsic muscles attached to the pectoral and pelvic arches, on the dorsal aspect.—In the fore limb, the *cleidomastoideus*, from the posterolateral region of the skull to the clavicle; the *trapezius*, from the skull and spines of many of the vertebræ to the scapula and clavicle; the *rhomboidei*, from the spines of vertebræ to the vertebral edge of the scapula, beneath the foregoing. Sometimes there is a *trachelo-acromialis*, from the transverse processes of the cervical vertebræ to the scapula.

On the ventral aspect, the *subclavius*, which passes from the anterior rib to the clavicle, may be regarded as, in part, a muscle of the limb; the *pectoralis minor*, from the ribs to the coracoid.

Between the dorsal and the ventral aspects muscular fibres arise from the cervical and dorsal ribs, and pass to the inner aspect of the vertebral end of the scapula: anteriorly, these are called *levator anguli scapulæ*; posteriorly, *serratus magnus*.

An *omohyoid* muscle frequently connects the scapula with the hyoidean arch.

The posterior limb does not seem to offer any muscles exactly homologous with the foregoing. So far, however, as the *recti abdominis*, the *obliquus externus*, and the fibres of the *erector spinæ*, are attached to the pelvic girdle, they correspond in a general way with the pre-axial, or protractor, muscles of the pectoral arch; and the ischio-coccygeal muscles, when they are developed, are, in relation to the pelvic arch, retractors, though, owing to the relative fixity of the pelvis, they act in protracting, or flexing, the caudal region.

The *psoas minor*, proceeding from the under-surfaces of posterior dorsal (or lumbar) vertebræ to the ilium, or pubis, is a protractor of the pelvis, but, as a hyposkeletal muscle, has no homologue in the fore limb.

Extrinsic muscles attached to the humerus or femur, on the dorsal aspect.—In the fore limb there is the post-axial *latissimus dorsi* passing from spines of dorsal vertebræ to the humerus. On the ventral aspect, the *pectoralis major* extends from the sternum and ribs to the humerus.

In the hind limb, the *glutæus maximus*, so far as it arises from the sacral and coccygeal vertebræ, and is inserted into the femur, repeats the relations of the *latissimus dorsi*. In the absence of anything corresponding with the sternum, or the ribs, no exact homologue of the *pectoralis major* can be said to exist, though the *pectineus* comes near it. The *psoas major*, passing from posterior dorsal or lumbar vertebræ—the *pyriformis* from sacral vertebræ—the *femoro-coccygeus* (when it exists) from caudal vertebræ—to the femur, are all hyposkeletal muscles, without homologues in the anterior extremity.

All the other muscles of the limbs are *intrinsic*, taking their origins from the pectoral or pelvic arches, or from some of the more proximal segments of the limb-skeleton, and having their insertion in the more distal segments. They are thus arranged in Man and the higher *Mammalia* :

Intrinsic muscles proceeding from the pectoral or pelvic

arches to the humerus or femur, on the dorsal aspect.—In the fore limb, the *deltoides* proceeds from the clavicle and scapula to the humerus. This superficial shoulder-muscle continues the direction of the fibres of the *trapezius*; and, when the clavicle is rudimentary, the adjacent portions of the two muscles coalesce into a *cephalo-humeralis* muscle. Beneath the deltoid the *supra-spinatus*, on the pre-axial side of the spine of the scapula; the *infra-spinatus*, and the *teres major* and *minor*, on its post-axial side, run from the dorsal aspect of the scapula to that of the head of the humerus.

In the hind limb, the *tensor vaginæ femoris*, which passes from that part of the ilium which corresponds with the spine and acromion of the scapula, to the femur, appears to answer better to the deltoid than does the *glutæus maximus*, which, at first sight, would seem to be the homologue of that muscle.

The *iliacus*, proceeding from the inner surface of the crest of the ilium to the smaller trochanter, answers to the *supra-spinatus*; the *glutæus medius* and *minimus*, which arise from the outer surface of the ilium, to the *infra-spinatus* and *teres*.

In the fore limb, a muscle, the *subscapularis*, is attached to the inner face of the scapula, and is inserted into the humerus. No muscle exactly corresponding with this appears to exist in the hind limb.

On the ventral aspect in the fore limb, the *coracobrachialis* passes from the coracoid to the humerus. In the hind limb, a number of muscles proceed from the corresponding (ischio-pubic) part of the pelvic arch to the femur. These are, from the outer surface of the pubis, the *pectineus*, and the great *adductors* of the femur; with the *obturator externus*, from the outer side of the ischiopubic fontanelle, or obturator membrane. The *gemelli* and the *quadratus femoris* take their origin from the ischium.

No muscle is attached to the proper inner surface of the ilium, so that there is no homologue of the *subscapularis* in the hind limb. On the other hand, a muscle, the *obturator internus*, attached to the inner surface of the ischiopubic fontanelle, and winding round to the femur, has no homo-

logue in the upper extremity of the higher *Vertebrata*, unless it be the so-called *coracobrachialis*, which arises from the inner surface of the coracoid in many *Sauropsida*.

Muscles of the Antebrachium and Crus.—On the dorsal aspect of the fore limb, as of the hind limb, certain muscles arise in part from the arch, and, in part, from the bone of the proximal segment of the limb, and go to be inserted into the two bones of the second segment. These are, in the fore limb, the *triceps extensor* and the *supinator brevis*; in the hind limb, the *quadriceps extensor*.

There is this difference between these two homologous groups of muscles—that in the fore limb, the principal mass of the muscular fibres goes, as the *triceps*, to be inserted into the post-axial bone (ulna), and the less portion, as *supinator brevis*, into the pre-axial bone (radius); whereas, in the hind limb, it is the other way, almost the whole of the muscular fibres passing, as the *quadriceps*, to the pre-axial bone (tibia), the tendon commonly developing a sesamoid *patella*; while only a few fibres of that division of the *quadriceps* which is called the “*vastus externus*” pass to the post-axial bone (fibula).

On the *ventral aspect*, the fore limb presents three muscles, arising either from the pectoral arch, or from the humerus, and inserted into the two bones of the forearm. On the pre-axial side are two muscles; one double-headed, the *biceps*, arising from the scapula and the coracoid, and inserted into the radius. A second, the *supinator longus*, passes from the humerus to the radius. On the post-axial side, the *brachialis anticus* arises from the humerus, and is inserted into the ulna. The hind limb has two muscles, the *sartorius*, arising from the ilium, and the *gracilis*, from the pubis, in place of the *biceps brachii*, and inserted into the pre-axial bone, the tibia, which corresponds with the radius. Two other muscles, the *semi-membranosus* and *semi-tendinosus*, pass from the ischium to the tibia, and replace, without exactly representing, the *supinator longus*. Corresponding with the *brachialis anticus* is the short head of the *biceps femoris*, arising from the femur, and inserted into the post-

axial bone of the leg, the fibula. The long head of the *biceps femoris*, which proceeds from the ischium, appears to have no representative in the fore limb.

In the fore limb, a muscle, the *pronator teres*, passes obliquely from the post-axial condyle of the humerus to the radius. In the hind limb, a corresponding muscle, the *popliteus*, proceeds from the post-axial condyle of the femur to the tibia. The *pronator quadratus*, which passes from the ulna to the radius, has its analogue, in some *Marsupialia* and *Reptilia*, in muscles which extend from the fibula to the tibia.

The Muscles of the Digits.—The remaining muscles of the two limbs are, primarily, muscles of the digits, and are attached either to the basi-digital (metacarpal or metatarsal) bones, or to the phalanges, though they may acquire secondary connections with bones of the tarsus or carpus. The plan upon which they are arranged, when they are most completely developed, will be best understood by commencing with the study of their insertion in any one of those digits which possesses a complete set; such, for example, as the fifth digit of the manus, or little finger, in Man and the higher *Primates*.

On the dorsal aspect this digit presents: first, attached to the base of its metacarpal bone, the tendon of a distinct muscle, the *extensor carpi ulnaris*. Secondly, spreading out over the phalanges into an aponeurosis, which is principally attached to the first and second, is a tendon belonging to another muscle, the *extensor minimi digiti*. Thirdly, entering the same expansion is one tendon of the *extensor communis digitorum*.

On the ventral aspect there are: first, attached to the base of the metacarpal, the tendon of a distinct muscle, the *flexor carpi ulnaris*; secondly, arising from the sides and ventral face of the metacarpal, and inserted into either side of the base of the proximal phalanx, two muscles, the *interossei*; thirdly, inserted into the sides of the middle phalanx by two slips, a tendon of the *flexor perforatus*; and fourthly, passing between these two slips, and inserted into the base

of the distal phalanx, a tendon of the *flexor perforans*. Thus there are special depressors, or flexors, for each segment of the digit. There appear, at first, to be but three elevators, or extensors, but, practically, each segment has its elevator. For the tendons of the *extensor communis* and *extensor minimi digiti* are attached to the middle and the proximal phalanges; and the distal phalanx is specially elevated by the tendons of two little muscles, which, in Man, are usually mere subdivisions of the *interossei*, and pass upwards,

Fig. 17.

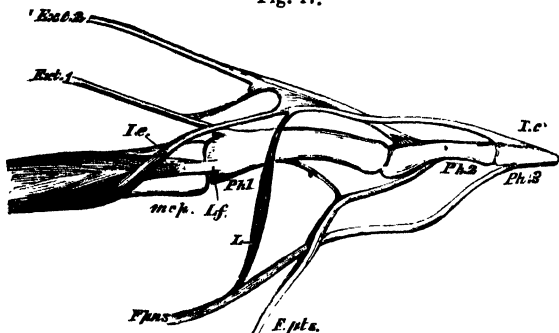


Fig. 17.—Part of the middle digit of the manus of an Orang with the flexors and extensors of the phalanges:—mcp., metacarpal bone; Ph. 1, Ph. 2, Ph. 3, the three phalanges; Ert. 1, the deep long extensor tendon from the *extensor indicis*; Ert. 2, the superficial long extensor tendon from the *extensor communis*; I.e. the interosseous short extensor; I.f. the interosseous short flexor; F.pns. the deep long flexor (*perforans*); F.pts. the superficial long flexor (*perforatus*).

joining the extensor sheath, to be finally inserted into the distal phalanx.

The fifth digit of the pes, or little toe, sometimes presents the same disposition of muscles, namely:

On the dorsal aspect: first, the *peronæus tertius* for the metatarsal bone; secondly, one tendon from the *extensor digitorum brevis*, but this last is commonly absent in Man; thirdly, one tendon from the *extensor digitorum longus*.

On the ventral aspect: first, the *peronæus brevis*, attached

to the base of the metatarsal; secondly, two *interossei*; thirdly, a perforated flexor; and fourthly, a perforating flexor, like those of the manus. The divisions of the *interossei*, which send tendons to the extensor sheath on the dorsum of the digits of the foot in Man, are hardly distinct from the ventral divisions of those muscles.

In addition to the muscles which have been mentioned, the fifth digit has an *abductor* and an *adductor*, which may be regarded as subdivisions of the *interossei*, arising within the manus or pes, and inserted into opposite sides of the proximal phalanx; and an *opponens*, a muscle attached to the ventral face of the carpus or the tarsus, and inserted into the post-axial edge of the shaft of the metacarpal or metatarsal.

Finally, a *lumbricalis* muscle proceeds from the tendon of the perforating flexor, on the pre-axial side of the digit, to the extensor sheath.

None of the other digits of the manus, or of the pes, has a greater number of muscles than this; in fact, all the others have fewer muscles, some of those enumerated being suppressed. What are often regarded as muscles special to man, such as the *extensor proprius indicis* and *extensor minimi digiti*, are only remains of muscles which are more fully developed in lower mammals, and send tendons to all four of the ulnar digits.

Only the pollex has an *opponens*.* Only the pollex and hallux have *adductors* and *abductors*. Some of the digits lack one or more of the ventral, or of the dorsal, muscles.

The correspondence between the muscles which have been mentioned, at their insertion in the digits, is clear enough, but some difficulties present themselves when the muscles are traced to their origins.

In Man the flexors and extensors of the digits (except the *interossei*) of the fore limb, arise in part from the humerus, and in part from the bones of the forearm, but not within the manus. On the contrary, none of the flexors and extensors of the digits of the pes arise from the femur, while some of them arise within the pes itself. The origins of

* I have seen an *opponens* in the hallux of an Orang.

the muscles seem to be, as it were, higher up in the fore limb than in the hind limb. Nevertheless, several of the muscles correspond very closely. Thus, on the dorsal aspect, the *extensor ossis metacarpi pollicis* passes from the post-axial side of the proximal region of the antebrachium obliquely to the trapezium and the metacarpal of the pollex, just as its homologue, the *tibialis anticus*, passes from the post-axial side of the upper part of the leg to the entocuneiform and the base of the metatarsal of the hallux; the two muscles correspond exactly. But the extensors of the phalanges of the pollex, and the deep extensors of the other digits of the manus, arise on the same side of the antebrachium, below the *extensor ossis metacarpi pollicis*; while, in the leg, one of the deep extensors of the hallux, and all those of the other digits, arise still lower down, viz. from the calcaneum.

Not less remarkable is the contrast between the more superficial sets of extensors in the two limbs. In the fore limb, proceeding from the pre-axial to the post-axial side, the following extensor muscles arise from the external or pre-axial condyle of the humerus: the *extensor carpi radialis longus* to the base of the second metacarpal; the *extensor carpi radialis brevis* to the base of the third metacarpal; the *extensor communis digitorum* to the four ulnar digits; the *extensor minimi digiti* to the fifth digit; the *extensor carpi ulnaris* to the base of the fifth metacarpal. In the hind limb, there are no homologues of the first two of these muscles. The homologue of the *extensor communis* is the long extensor, which arises, not from the femur, but from the fibula. The *peronæus tertius*,* passing from the dorsal face of the fibula to the fifth metatarsal, is the only representative of the *extensor carpi ulnaris*.

On the ventral aspect of the human fore limb, two deep

* This muscle, which lies altogether on the dorsal face of the hind limb, and which I have seen only in Man, should not be confounded, as it often is, with one or more muscles, the *peronæi 3tii, 4ti, et 5ti digiti*, which are very

often developed in other *Mammalia*, but arise on the ventral face of the fibula, and send their tendons below the external malleolus to the extensor sheaths of the fifth, fourth, and even third digits.

flexors arise from the radius, ulna, and interosseous membrane, and run parallel with one another, though disconnected, to the digits. These are, on the pre-axial side—the *flexor pollicis longus*, to the distal phalanx of the pollex; and the *flexor digitorum perforans*, to the distal phalanges of the other digits.

In the hind limb, two homologous muscles, the *flexor hallucis longus* and the *flexor digitorum perforans*, arise from the tibia and fibula and interosseous membrane, and their tendons are distributed to the distal phalanges of the digits. But, before they divide, the tendons become connected together in such a way, that many of the digits receive tendinous fibres from both sources.

In the fore limb, there are no other deep flexors, but the internal, or post-axial, condyle of the humerus gives origin to a number of muscles. These, proceeding from the pre-axial to the post-axial side, are the *flexor carpi radialis* to the base of the second metacarpal; the *palmaris longus* to the fascia of the palm, the *flexor perforatus digitorum* to the middle phalanges of the four ulnar digits; the *flexor carpi ulnaris* to the base of the fifth metacarpal. The sesamoid, pisiform bone is developed in the tendon of the last muscle.

The only muscle which exactly corresponds with any of these, in the hind limb, is the *plantaris*; which, in Man, is a slender and insignificant muscle proceeding from the outer (post-axial) condyle of the femur to the plantar fascia—and answers to the *palmaris longus*. In many quadrupeds, as the Rabbit and Pig, the *plantaris* is a large muscle, the tendon of which passes over the end of the calcaneal process ensheathed in the *tendo-achillis*, and divides into slips, which become the perforated tendons of more or fewer of the digits. The *flexor carpi radialis* is also roughly represented by the *tibialis posticus*—a muscle which passes from the tibia and interosseous membrane to the entocuneiform, and therefore differs in insertion, as well as in origin, from its analogue in the fore limb. The *flexor perforatus digitorum* of the foot takes its origin sometimes from the calcaneum; sometimes, in part from the calcaneum, and in

part from the perforating flexor; or it may be closely connected with the tendons of the *plantaris*. The *peronæus brevis* represents the *flexor carpi ulnaris* by its insertion, but it arises no higher than the fibula, and has no sesamoid.

Two most important muscles yet remain to be considered in the leg. The one of these is that which is inserted by the *tendo-achillis* into the calcaneum, and arises by four heads, two from the condyles of the femur (called *gastrocnemius*), and two from the tibia and fibula (called *soleus*). The other muscle is the *peronæus longus*, arising from the fibula, passing behind the external malleolus, and then crossing the foot to the base of the metatarsal of the hallux.

The latter muscle does not appear to have any representative in the fore limb. The *gastrocnemius* and *soleus* may possibly represent the crural part of the perforated flexor, since in many of the *Vertebrata*, the *tendo-achillis* is but loosely connected with the calcaneum, and passes over it into the plantar fascia and the perforated tendons. A peculiar adductor muscle of the hallux in Man and Apes is the *transversalis pedis*, which is inserted into the basal phalanx of the hallux, and arises from the distal ends of the metatarsals of the other digits. The muscle sometimes has an analogue in the manus.

Electrical Organs.—Certain fishes belonging to the genera *Torpedo* (among the *Elasmobranchii*), *Gymnotus*, *Malapterurus*, and *Mormyrus* (among the *Teleostei*), possess organs which convert nervous energy into electricity, just as muscles convert the same energy into ordinary motion, and therefore may well be mentioned in connection with the nervous system. The "electrical organ" is always composed of nearly parallel lamellæ of connective tissue, inclosing small chambers, in which lie what are termed the *electrical plates*. These are cellular structures, in one face of which the final ramifications of the nerves, which are supplied to the organ by one or many trunks, are distributed. The face on which the nerves ramify is in all

the plates the same, being inferior in *Torpedo*, where the lamellæ are disposed parallel to the upper and under surfaces of the body; posterior in *Gymnotus*, and anterior in *Malapterurus*, the lamellæ being disposed perpendicularly to the axis in these two fishes. And this surface, when the discharge takes place, is always negative to the other.

Fig. 18.

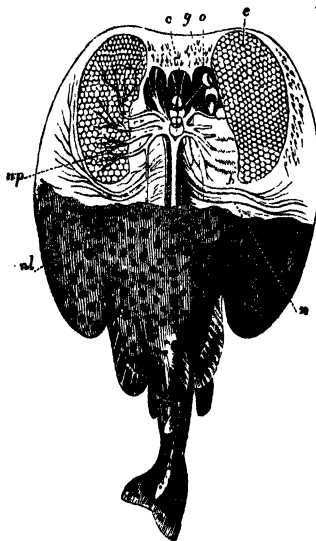


Fig. 18.—The *Torpedo*, with its electrical apparatus displayed.—*b*, branchiæ; *c*, brain; *e*, electric organ; *g*, cranium; *m e*, spinal cord; *n*, nerves to the pectoral fins; *nl*, *nervi laterales*; *np*, branches of the pneumogastric nerves going to the electric organ; *o*, eye.

In *Torpedo* the nerves of the electrical organs proceed from the fifth pair, and from the “electric lobe” of the *medulla oblongata*, which appears to be developed at the origin of the pneumogastrics. In the other electrical fishes

the organs are supplied by spinal nerves; and in *Malapterurus*, the nerve consists of a single gigantic primitive fibre, which subdivides in the electrical organ.

The ordinary Rays possess organs of much the same structure as the electrical apparatus, at the sides of the tail.

The Nervous System: the Encephalon.—In all vertebrated animals except *Amphioxus*, the brain exhibits that separation into a *fore-brain*, *mid-brain*, and *hind-brain*, which results from its embryonic division by two constrictions, into the three thin-walled vesicles—the anterior, middle, and posterior cerebral vesicles—already mentioned. The cavities of these vesicles—the primitive ventricles of the brain—freely communicate at first, but become gradually diminished by the thickening of their sides and floors. The cavity of the anterior vesicle is, in the adult human brain, represented by the so-called *third ventricle*; that of the middle vesicle, by the *iter a tertio ad quartum ventriculum*; that of the posterior vesicle, by the *fourth ventricle*.

The floor and sides of the posterior vesicle, in fact, thicken and become the *medulla oblongata*; together with the *pons varolii*, in those animals which possess the latter structure. The posterior part of the roof is not converted into nervous matter, but remains thin and attenuated; the *ependyma*, or lining of the cerebral cavity, and the *arachnoid*, or serous membrane which covers the brain externally, coming nearly into contact, and forming, to all appearance, a single thin membrane, which tears with great readiness, and lays open the cavity of the fourth ventricle. Anteriorly, on the other hand, the roof becomes converted into nervous matter, and may enlarge into a complex mass, which overhangs the posterior division, and is called the *cerebellum*. The *pons varolii*, when it exists, is the expression of commissural fibres, which are developed in the sides and floor of the anterior part of the posterior cerebral vesicle, and connect one half of the cerebellum with the other.

Thus the *hind-brain* differs from the posterior cerebral vesicle in being differentiated into the medulla oblongata

(or *myelencephalon*) behind, and the cerebellum with the pons varolii (which together constitute the *metencephalon*) in front.

Fig. 19.

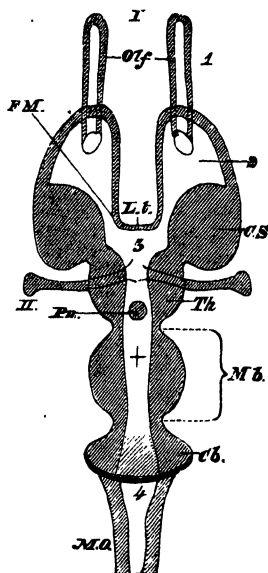


Fig. 19.—Diagrammatic horizontal section of a Vertebrate brain. The following letters serve for both this figure and Fig. 20:—*Mb*, Mid-brain. What lies in front of this is the fore-brain, and what lies behind, the hind-brain. *L.t.* the lamina terminalis; *Olf*, the olfactory lobes; *Hmp*, the hemispheres; *Th.E*, the thalamencephalon; *Pn*, the pineal gland; *Py*, the pituitary body; *FM*, the foramen of Munro; *CS*, the corpus striatum; *Th*, the optic thalamus; *CQ*, the corpora quadrigemina; *CC*, the crura cerebri; *Cb*, the cerebellum; *PV*, the pons varolii; *MO*, the medulla oblongata; *I*, olfactorii; *II*, optici; *III*, point of exit from the brain of the motores oculorum; *IV*, of the pathetici; *VI*, of the abducentes; *V-XII*, origins of the other cerebral nerves. 1, olfactory ventricle; 2, lateral ventricle; 3, third ventricle; 4, fourth ventricle; +, iter a tertio ad quartum ventriculum.

The floor of the middle cerebral vesicle thickens, and becomes converted into two great bundles of longitudinal

fibres, the *crura cerebri*. Its roof, divided into two, or four, convexities by a single longitudinal, or a crucial, depression, is converted into the "optic lobes," *corpora bigemina* or *quadrigemina*. And these parts, the optic lobes, the *crura cerebri*, and the interposed cavity, which either retains the form of a ventricle, or is reduced to a mere canal (the *iter a tertio ad quartum ventriculum*), are the components of the *mid-brain* or *mesencephalon*.

Fig. 20.

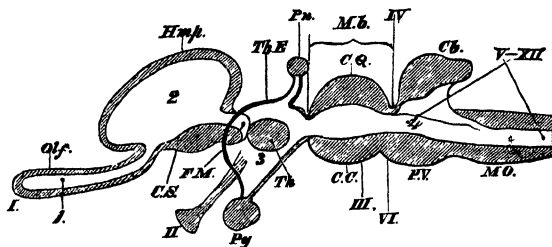


Fig. 20.—A longitudinal and vertical section of a Vertebrate brain. The letters as before. The *lamina terminalis* is represented by the strong black line between *FM* and 3.

The anterior cerebral vesicle undergoes much greater changes than either of the foregoing; for, in the first place, it throws out from its anterior lateral parietes two hollow prolongations, the *hemispheres* (or *prosencephala*), and each of these again protrudes from its anterior end a smaller hollow process, the *olfactory lobe* (or *rhinencephalon*). By the development of these processes the anterior vesicle becomes divided into five parts—one median and posterior, and four anterior and paired. The median and posterior, which remains as the representative of the greater part of the original anterior cerebral vesicle, is the *vesicle of the third ventricle* (or *thalamencephalon*). Its floor is produced into a conical process, the *infundibulum*, the blind end of which is connected with the pituitary body, or *hypophysis cerebri*. Its sides thicken greatly, acquire a ganglionic

structure, and become the *optic thalami*. Its roof, on the other hand, resembles that of the fourth ventricle, in remaining very thin, and, indeed, a mere membrane. The pineal gland, or *epiphysis cerebri*, is developed in connection with the upper wall of the third ventricle; and, at the sides of its roof, are two nervous bands, which run to the pineal gland, and are called its peduncles.

The front wall of the vesicle, in part, becomes the so-called *lamina terminalis*, which is the delicate anterior boundary of the third ventricle. In certain directions, however, it thickens and gives rise to three sets of fibres, one transverse and two vertical—the former lying in front of the latter. The transverse fibres pass on either side into the *corpora striata*, and constitute the *anterior commissure* which connects those bodies. The vertical fibres are the *anterior pillars of the fornix*, and they pass below into the floor of the third ventricle, and into the *corpora mammillaria*, when those structures are developed.

The outer and under wall of each cerebral hemisphere thickens and becomes the *corpus striatum*, a ganglionic structure which, from its origin, necessarily abuts against the outer and anterior part of the *optic thalamus*. The line of demarcation between the two corresponds with the lower lip (*tænia semicircularis*) of the aperture of communication (called the *foramen of Munro*) between the third ventricle and the cavity of the cerebral hemisphere, which is now termed the *lateral ventricle*. In the higher *Vertebrata*, the upper lip of the foramen of Munro thickens, and becomes converted into a bundle of longitudinal fibres, which is continuous, anteriorly, with the anterior pillars of the fornix before mentioned. Posteriorly, these longitudinal fibres are continued backwards and downwards along the inner wall of the cerebral hemisphere, following the junction of the *corpora striata* and *optic thalami*, and pass into a thickening of the wall of the hemisphere, which projects into the *lateral ventricle*, and is called the *hippocampus major*. Thus a longitudinal commissural band of nervous fibres, extending from the floor of the third ventricle to that of the lateral

tricle, and arching over the foramen of Munro, is produced. The fibres of opposite sides unite over the roof of the third ventricle, and constitute what is called the body of the *fornix*. Behind this union the bands receive the name of the *posterior pillars of the fornix*.

The optic thalami may be connected by a grey soft commissure; and a *posterior commissure*, consisting of transverse nerve-fibres, is generally developed between the posterior ends of the two thalami.

In the *Mammalia*, a structure, which is absent in other *Vertebrata*, makes its appearance; and, in the higher members of that class, this *corpus callosum* is the greatest and most important mass of commissural fibres. It is a series of transverse fibres, which extends from the roof of one lateral ventricle to that of the other, across the interval which separates the inner wall of one hemisphere from that of the other.

When the corpus callosum is largely developed, its anterior part crosses the interspace between the hemispheres considerably above the level of the fornix; so that between the fornix and it, a certain portion of the inner wall of each hemisphere, with the intervening space, is intercepted. The portion of the two inner walls and their interspace, thus isolated from the rest, constitutes the *septum lucidum*, with its contained *fifth ventricle*.

The Modifications of the Brain.—The chief modifications in the general form of the brain arise from the development of the hemispheres relatively to the other parts. In the lower vertebrates the hemispheres remain small, or of so moderate a size as not to hide, by overlapping, the other divisions of the brain. But, in the higher *Mammalia*, they extend forwards over the olfactory lobes, and backwards over the optic lobes and cerebellum, so as completely to cover these parts; and, in addition, they are enlarged downwards towards the base of the brain. The cerebral hemisphere is thus, as it were, bent round its *corpus striatum*, and it becomes distinguished into regions, or *lobes*, which are not separated by any very sharp lines of demarcation. These regions are named the *frontal*, *parietal*,

occipital, and *temporal* lobes—while, on the outer side of the *corpus striatum*, a *central* lobe (the *insula* of Reil) lies in the midst of these. The lateral ventricles are prolonged into the frontal, occipital, and temporal lobes, and acquire what are termed their *anterior*, *posterior*, and *descending cornua*.

Furthermore, while, in the lower vertebrates, the surface of the cerebral hemispheres is smooth; in the higher, it becomes complicated by ridges and furrows, the *gyri* and *sulci*, which follow particular patterns. The superficial vascular layer of connective tissue which covers the brain, and is called *pia mater*, dips into these sulci: but the *arachnoid*, or delicate serous membrane, which, on the one hand, covers the brain, and, on the other, lines the cranium, passes from convolution to convolution without entering the sulci. The dense periosteal membrane which lines the interior of the skull, and is itself lined by the parietal layer of the *arachnoid*, goes by the name of the *dura mater*.

The general nature of the modifications observable in the brain as we pass from the lower to the higher *mammalia* is very well shown by the accompanying figures of the brain of a Rabbit, a Pig, and a Chimpanzee (Figs. 21 & 22).

In the Rabbit, the cerebral hemispheres leave the cerebellum completely exposed when the brain is viewed from above. There is but a mere rudiment of the Sylvian fissure at *Sy*, and the three principal lobes, frontal (*A*), occipital (*B*), and temporal (*C*), are only indicated. The olfactory nerves are enormous, and pass by a broad smooth tract, which occupies a great space in the lateral aspect of the brain, into the natiform protuberance of the temporal lobe (*C*).

In the Pig, the olfactory nerves and tract are hardly less conspicuous; but the natiform protuberance is more sharply notched off, and begins to resemble the unciform gyrus in the higher *Mammalia*, of which it is the homologue. The temporal gyri (*C*¹), though still very small, begin to enlarge downwards and forwards over this. The upper part of the cerebral hemisphere is much enlarged, not only in the frontal, but also in the occipital region, and to a great extent

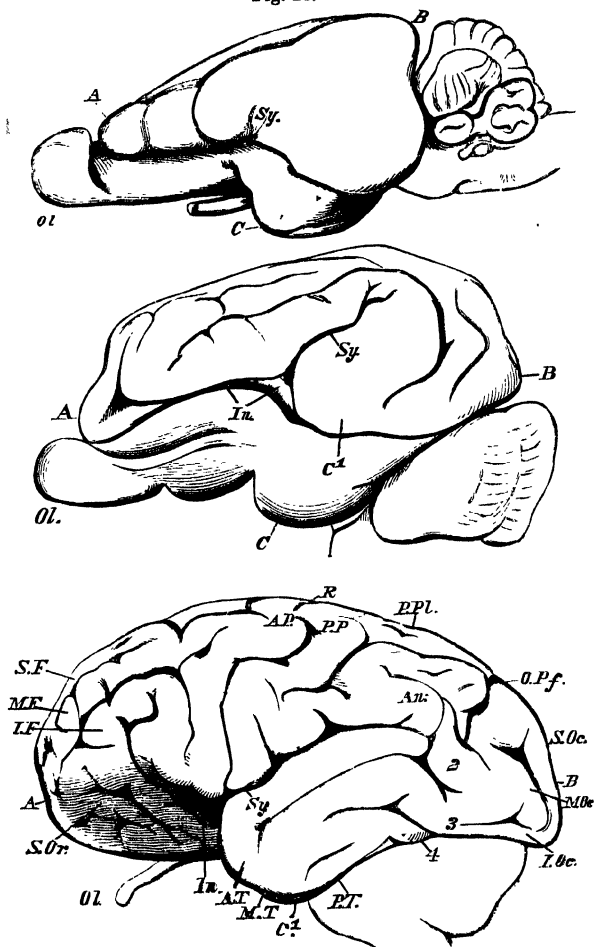


Fig. 21.—Lateral views of the brains of a Rabbit, a Pig, and a Chimpanzee, drawn of nearly the same absolute size. The Rabbit's brain is at the top; the Pig's, in the middle, the Chimpanzee's, lowest.

Ol, the olfactory lobe; *A.*, the frontal lobe; *B.*, the occipital lobe; *C.*, the temporal lobe; *Sy.*, the Sylvian fissure; *In.*, the insula; *S. Or.*, supraorbital; *S.F.*, *M.F.*, *I.F.*, superior, middle, and inferior frontal gyri; *A.P.*, antero-parietal; *P.P.*, postero-parietal gyri; *R.*, sulcus of Rolando; *P.Pl.*, postero-parietal lobule; *O.Pf.*, external perpendicular or occipito-temporal sulcus; *An.*, angular gyrus; 2, 3, 4, annectent gyri; *A.T.*, *M.T.*, *P.T.* the three temporal, and *S.Oc.*, *M.Oc.*, *I.Oc.* the three occipital gyri.

hides the cerebellum when the brain is viewed from above. What in the Rabbit was a mere angulation at *Sy*, in the Pig has become a long sulcus—the *Sylvian fissure*, the lips of which are formed by a gyrus, the *Sylvian*, or *angular*, gyrus. Two other sets of gyri, more or less parallel with this, are visible upon the outer surface of the hemisphere; and at the entrance of the Sylvian fissure, at *In*, there is an elevation which answers to the *insula*, or *central lobe*.

In the Chimpanzee, the olfactory nerves, or rather lobes, are, relatively, very small, and the tracts which connect them with the uncinate gyri (*substantiæ perforatæ*) are completely hidden by the temporal gyri (*C*¹). The Sylvian fissure is very long and deep, and begins to hide the *insula*, on which a few fan-shaped gyri are developed. The frontal lobes are very large, and overlap the olfactory nerves for a long distance; while the occipital lobes completely cover and extend beyond the cerebellum, so as to hide it completely from an eye placed above. The gyri and sulci have now attained an arrangement which is characteristic of all the highest *Mammalia*. The fissure of Rolando (*R*) divides the antero-parietal gyrus (*A.P*) from the postero-parietal (*P.P*). These two gyri, with the postero-parietal lobule (*P.Pl.*), and part of the angular gyrus (*An*), constitute the *Parietal lobe*. The *frontal lobe*, which lies anterior to this, the *occipital lobe*, which lies behind it, and the *temporal lobe*, which lies below it, each present three tiers of gyri, which, in the case of the frontal and occipital lobes, are called superior, middle, and inferior—in that of the temporal lobe, anterior, middle, and posterior. The inferior surface of the frontal lobe, which lies on the roof of the orbit (*S. Or.*), presents many small sulci and gyri.

On the inner face of the cerebral hemisphere (Fig. 22)

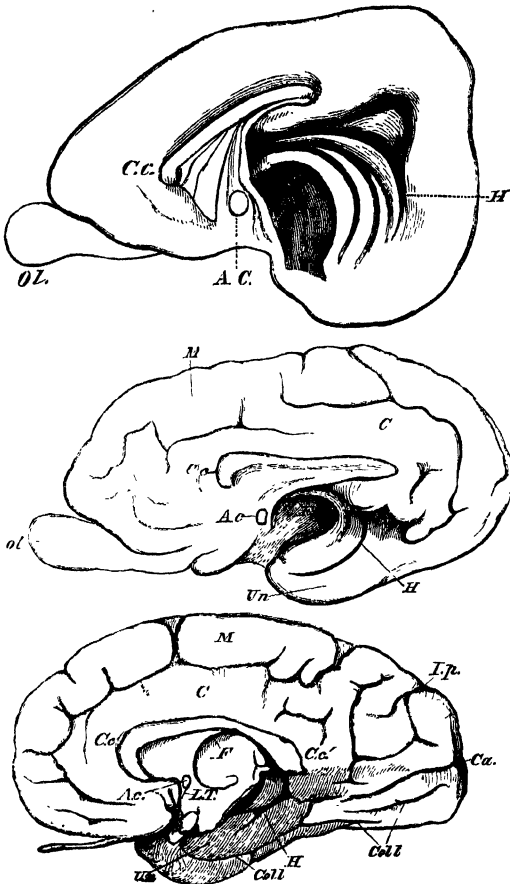


Fig. 22.—Inner views of the cerebral hemispheres of the Rabbit, Pig, and Chimpanzee. drawn as before, and placed in the same order. *OL*, olfactory lobe; *C.c.* corpus callosum; *A.c.* anterior commissure; *H*, hippocampal sulcus; *Un*, uncinate; *M*, marginal; *C*, callosal gyri; *I.p.* internal perpendicular; *Ca.* calcarine; *Coll*, collateral sulci; *F*, fornix.

the only sulcus presented by the Rabbit's brain is that deep and broad depression (*H*), which runs parallel with the posterior pillar of the fornix, and gives rise, in the interior of the descending cornu of the lateral ventricle, to the projection which is termed the *hippocampus major*. In the Pig, this *hippocampal sulcus* (*H*) is much narrower and less conspicuous; and a *marginal* (*M*) and a *callosal* (*C*) gyrus are separated by a well-marked *calloso-marginal* sulcus. As in the Rabbit, the uncinatè gyrus forms the inferior boundary of the hemisphere. In the Chimpanzee, the marginal and callosal gyri are still better marked. There is a deep internal perpendicular, or *occipito-parietal*, sulcus (*I.p*). The *calcarine* sulcus (*Ca*) causes a projection into the floor of the posterior cornu, which is the *hippocampus minor*; while the *collateral* sulcus (*Coll*) gives rise to the eminence of that name in both the posterior and descending cornua. The hippocampal sulcus (*H*) is relatively insignificant, and the lower edge of the temporal lobe is formed by the posterior temporal gyrus.

In the Rabbit, the corpus callosum is relatively small, much inclined upwards and backwards; and its anterior extremity is but slightly bent downwards, so that the so-called *genu* and *rostrum* are inconspicuous. The Pig's corpus callosum is larger, more horizontal, and possesses more of a rostrum: in the Chimpanzee, it is still larger, somewhat deflexed, and very thick posteriorly; and has a large rostrum. In proportion to the hemispheres, the anterior commissure is largest in the Rabbit and smallest in the Chimpanzee. The Rabbit and the Pig have a single *corpus mammillare*, the Chimpanzee has two. The cerebellum of the Rabbit is very large in proportion to the hemispheres, and is left completely uncovered by them in the dorsal view. Its median division, or *vermis*, is straight, symmetrical, and large in proportion to the lateral lobes. The *flocculi*, or accessory lobules developed from the latter, are large, and project far beyond the margins of the lateral lobes. The ventral face of the metencephalon presents on each side, behind the posterior margin of the pons

varolii, flattened rectangular areas, the so-called *corpora trapezoidea*.

In the Pig, the cerebellum is relatively smaller, and is partially covered by the hemispheres; the lateral lobes are larger in proportion to the vermis and the flocculi, and extend over the latter. The *corpora trapezoidea* are smaller. In the *Chimpanzee*, the relatively still smaller cerebellum is completely covered; the vermis is very small in relation to the lateral lobes, which cover and hide the insignificant flocculi. There are no *corpora trapezoidea*.

In all the characters now mentioned the brain of Man differs far less from that of the *Chimpanzee* than that of the latter does from the Pig's brain.

The Myelon.—The spinal canal, and the cord which it contains, are lined by continuations of the three membranes which protect the encephalon. The cord is sub-cylindrical, and contains a median longitudinal canal, the *canalis centralis*, the remains of the primitive groove. It is divided by anterior and posterior median fissures into two lateral halves, which are, usually, connected only by the comparatively narrow isthmus, which immediately surrounds the *canalis centralis*. The cord may, in the adult, extend through the whole spinal canal, or it may come to an end at any point between the caudal extremity and the anterior thoracic region.

The distribution of the two essential constituents of nervous tissue, ganglionic corpuscles and nerve-fibres, is very definite in the spinal cord, ganglionic corpuscles being confined to the so-called "grey matter" which constitutes the isthmus, and spreads out into two masses, each of which ends in an anterior (or ventral) and a posterior (or dorsal) horn. Nerve-fibres also abound in the grey matter; but the so-called "white matter," which constitutes the external substance of the cord, contains only the fibrous nervous matter, and has no ganglionic corpuscles.

The spinal nerves arise in opposite pairs from the two halves of the cord, and usually correspond in number with

Fig. 23.

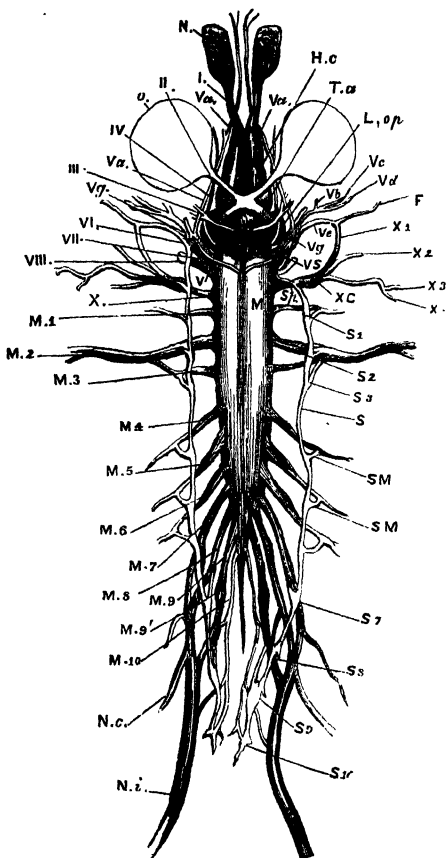


Fig. 23.—A diagrammatic view of the Chief Trunks of the Cerebro-spinal and Sympathetic Nervous Systems of *Rana esculenta* seen from below (twice the size of nature). I. The olfactory nerves. N. The olfactory sac. II. The optic nerve. O. The eye. L. op. The optic lobes. Ta. Optic tracts passing from the optic lobes to

the chiasma, behind which lies the pituitary body. III. *Oculomotorius*. IV. *Patheticus*. V. The trigeminal, with which the *abducens* (VI.), *facialis* (VII.), and the upper end of the sympathetic (V.S.), are closely connected. Branches of this nervous plexus are *V.a*, the nasal and ophthalmic branches of the fifth and the *abducens*. *V.b*, *c*, *d*, the palatine, maxillary, and mandibular branches of the fifth. *V.e*, the tympanic branch into which the proper facial nerve (VII.) enters, and, with a branch of the vagus, forms the so-called facial nerve of the Frog, *F*. VIII. The auditory nerve. *X*, with its branches *X₁*, *X₂*, *X₃*, *X₄*, represents the glossopharyngeal and the vagus. The medulla oblongata (*Myelencephalon*) ends, and the medulla spinalis (*Myelon*) begins, about the region marked by the letter *M*. *M* 1-10, the spinal nerves. *M* 2, the brachial nerves, *M* 7, 8, 9, the ischiatic plexus, from which proceed the crural (*N.c.*) and ischiatic (*N.i.*) nerves. *S*. The trunk of the sympathetic. *S.M.* The communicating branches with the spinal ganglia. *S* 1-10. The sympathetic ganglia.

the vertebræ through, or between, which they pass out (Fig. 23). Each nerve has two roots, one from the dorsal, and one from the ventral, region of its half of the cord. The former root has a ganglionic enlargement, and only contains sensory fibres; the latter has no ganglion, and exclusively contains motor fibres.* After leaving the vertebral canal, each spinal nerve usually divides into a dorsal and a ventral branch; but, in the Ganoid fishes, each of these branches is a distinct nerve, arising by its own proper roots.

The Cerebral Nerves.—The greatest number of pairs of nerves ever given off from the vertebrate brain is twelve, including the so-called olfactory nerves, and the optic nerves, which, as has been seen, are more properly diverticula of the brain, than nerves in the proper sense of the word.

The olfactory "nerves" (*olfactorii*) constitute the *first pair* of cerebral nerves. They always retain their primary connection with the cerebral hemispheres, and frequently contain, throughout life, a cavity, the *olfactory ventricle*, which communicates with the lateral ventricle.

The optic "nerves" (*optici*) are the *second pair* of cerebral nerves. In the Lampreys and Hags (*Marsipobranchii*) these nerves retain their embryonic origin from the thala-

* *Amphioxus* appears to be an exception to this, as to most other, rules of Vertebrate anatomy.

mencephalon, and each goes to the eye of its own side. In other *Vertebrata*, the nerves cross one another at the base of the brain (*Teleostei*), or are fused together into a *chiasma* (*Ganoidei*, *Elasmobranchii*, and all the higher *Vertebrata*). In the higher *Vertebrata*, again, the fibres of the optic nerves become connected chiefly with the mesencephalon.

All the other cerebral nerves differ from these in arising, not as diverticula of any of the cerebral vesicles, but by histological differentiation of the primitive brain-case, or *lamine dorsales* of the skull.

The *third* (*motores oculorum*) and *fourth* (*pathetici*) pairs of nerves are distributed to the muscles of the eye; the third to the majority of these muscles, the fourth to the superior oblique muscles. The third pair of nerves issues from the *crura cerebri*, or inferior division of the metencephalon, upon the base of the brain; the fourth pair, from the forepart of the upper division of the metencephalon, immediately behind the optic lobes, upon the superior surface of the brain. This region is known as the *Valve of Vieussens* in the *Mammalia*.

All the other cerebral nerves originate in the posterior division of the *hind-brain*—the myelencephalon. The great *fifth* pair (*trigemini*) passes out from the sides of the metencephalon, and supplies sensory nerves to the integument of the head, and motor nerves to most of the muscles of the jaws, by its three divisions—the *ophthalmic*, the *superior maxillary*, and the *inferior maxillary*, nerves.

Of these divisions the two latter are, very generally, closely connected together, while the ophthalmic division remains distinct. The ophthalmic division passes to the cleft between the trabecula and the maxillary process (which nearly corresponds with the orbit, and might be termed the *orbito-nasal* cleft), and is distributed to the inner and the outer side of that cleft. Hence its main branches are nasal and lachrymal. The two maxillary nerves, on the other hand, are distributed to the inner and outer sides, or anterior and posterior boundaries, of the buccal cleft. Hence the superior maxillary belongs to the posterior, or outer,

side of the maxillary process, while the inferior maxillary appertains to the anterior region of the first visceral arch. The superior maxillary commonly unites with the outer, or lachrymal, division of the ophthalmic; the inferior maxillary with the anterior division of the facial.

In the higher *Vertebrata*, the trigeminal nerve usually has two very distinct roots, a dorsal sensory, provided with a ganglion (the *Casserian* ganglion), and a ventral motor, non-ganglionated. The fibres of the latter pass almost exclusively into the inferior maxillary division. In addition, the ophthalmic division may have a ganglion (*ciliary*); the superior maxillary another (*sphenopalatine* or *Meckelian*), and the inferior maxillary a third (*otic*).

The *sixth* pair (*abducentes*) issues from the inferior surface of the brain, at the junction of the myelencephalon with the metencephalon. It supplies the external straight muscles of the eye; with the muscles of the nictitating membrane, and the *retractor bulbi*, or *musculus choanoides*, when such muscles exist.

The *seventh* pair (*faciales*) supplies the superficial facial muscles, and ultimately divides into two branches, one of which is in relation with the mandibular, and the other with the hyoidean arch.

The five nerves which have just been mentioned are often intimately connected together. Thus, in the *Lepidosiren*, the three motor nerves of the eyeball are completely fused with the ophthalmic division of the fifth.* In the *Myxinoid* fishes there are no motor nerves of the eyeball; but, in the Lamprey, the *rectus externus* and *inferior*, and the *obliquus inferior*, are supplied by the ophthalmic, while the oculomotor and the pathetic unite into a common trunk, which gives branches to the *rectus superior* and *internus*, and *obliquus superior*. The oculomotor, the pathetic, and the

* I am greatly disposed to think that the motor nerves of the eye more nearly retain their primary relations in *Lepidosiren* than in any other vertebrated animal; and that they are really the motor

portions of the nerves of the orbito-nasal cleft, the third and fourth appertaining to the inner division of the ophthalmic, the sixth to its outer division.

abducens, are more or less confounded with the ophthalmic in the *Amphibia*; but in *Teleostei*, *Ganoidei*, *Elasmobranchii*, and in all the higher *Vertebrata*, the nerves of the muscles of the eye are distinct from the fifth pair, except where the oculomotor unites with the ophthalmic into the ciliary ganglion.

The facial and the trigeminal nerves have common roots in fishes. In *Amphibia*, though the roots are distinct, the facial may be completely united with the ganglion of the trigeminal, as in the Frog. In all abbranchiate *Vertebrata* the two nerves are quite distinct.

Whether the nerves are distinct or not, a *palatine*, or *vidian*, nerve (which, in the higher *Vertebrata*, is especially connected with the facial) runs through, or beneath, the base of the skull, parallel with its long axis; and, after uniting with the superior maxillary, and usually contributing to form the *sphenopalatine*, or *Meckelian*, ganglion, is distributed to the mucous membrane of the roof of the mouth; and the mandibular division of the seventh, or *chorda tympani*, unites with the inferior maxillary division of the fifth nerve.

The *eighth* pair (*auditorii*) is formed by the nerves of the organ of hearing.

The *ninth* pair (*glossopharyngei*) is especially distributed to the pharyngeal and lingual regions of the alimentary canal, and, primarily, supplies the boundaries of the second visceral cleft.

The *tenth* pair (*pneumogastrici* or *vagi*) consists of very remarkable nerves, which pass to the gullet and stomach, the respiratory and vocal organs, to some parts of the integument of the body, and to the heart. In the *Ichthyopsida* they give off, in addition, long *lateral* nerves to the integuments of the sides of the body. In the higher *Vertebrata*, these lateral nerves are represented only by small branches distributed chiefly to the occipital region. The ninth and tenth pairs are both motor and sensory in function, and are often so intimately connected as to form almost one nerve.

The *eleventh* pair (*accessorii*) are cerebral only by courtesy, as these nerves take their origin from the spinal cord, by roots which issue between the proper anterior and posterior roots of the spinal nerves, and, joining together, form, on each side, a nerve which passes out with the pneumogastric, partly joining it, and partly going to muscles which arise from the head and anterior vertebræ, and are inserted into the pectoral arch.

The spinal accessory exists in no Ichthyopsid vertebrate, but is found in all *Sauropsida*, with the exception of the *Ophidia*, and in the *Mammalia*.

The *twelfth* and last pair (*hypoglossi*) are the motor nerves of the tongue, and of some retractor muscles of the hyoidean apparatus.

In the *Ichthyopsida* the first cervical nerve supplies the distributional area of the hypoglossal; but in all the abran- chiate *Vertebrata* there is a hypoglossal, which traverses a foramen in the ex-occipital, though it often remains closely connected with the first cervical, and may rather be regarded as a subdivision of that nerve, than as a proper cerebral nerve.

Thus the nerves arising from the hind-brain, in all the higher *Vertebrata*, fall into three groups: 1st, a sensori-motor, pre-auditory, set (3rd, 4th, 5th, 6th, 7th); 2nd, the purely sensory auditory nerve (8th); 3rd, the sensori-motor, post-auditory, set (9th, 10th, 12th).

The apertures by which several of these nerves leave the skull, retain a very constant relation to certain elements of the cranium on each side. Thus :

a. The filaments of the olfactory nerve always leave the cranium between the lamina perpendicularis, or body of the ethmoid, and its lateral or prefrontal portion.

b. The optic nerve constantly passes out behind the centre of the orbitosphenoid and in front of that of the alisphenoid.

c. The third division of the trigeminal, or fifth nerve, always leaves the skull behind the centre of the alisphenoid and in front of the pro-otic.

d. The glossopharyngeal and pneumogastric always make their exit behind the centre of the opisthotic, and in front of the centre of the ex-occipital.

The apertures for the exit of the cranial nerves denoted in the paragraphs, *a. b. c. d.*, when surrounded by bone, and well defined, are called respectively : *a*, the *olfactory foramen* ; *b*, the *optic foramen* ; *c*, the *foramen ovale* ; *d*, the *foramen lacerum posterius*. The adjacent bones may take equal shares in bounding these foramina, or the foramina may be altogether in one bone ; but their positions, as here defined, never change.

Another point to be especially considered respecting the general disposition of the cranial nerves, is the relation which some of them bear to the visceral arches and clefts, and which has already been incidentally mentioned. Thus, the seventh nerve is distributed to the posterior part of the first visceral arch, and to the anterior part of the second visceral arch, its two branches inclosing the first visceral cleft. In like manner, the ninth (glossopharyngeal) nerve is distributed to the hinder part of the second arch and to the front part of the third, its branches inclosing the second visceral cleft. The first branch of the pneumogastric has similar relations to the third and fourth arches and to the third cleft ; and in branchiate *Vertebrata*, the other anterior branches of the pneumogastric are similarly distributed to the successive branchial arches, the two divisions of each branch inclosing a branchial cleft.

The second and the third divisions of the trigeminal are distributed, in an analogous manner, to the anterior region of the first visceral arch, and to the posterior or outer region of the maxillo-palatine process—the gape of the mouth representing a visceral cleft between the two. The inner and outer portions of the first division of the trigeminal are similarly related to the inner, or anterior, region of the maxillo-palatine process, and the outer side of the *trabecula cranii*—the orbito-nasal fissure representing the cleft between the two.

Considerations of this kind suggest that the trabeculæ

and the maxillo-palatine processes may represent pre-oral sceral arches, which are bent forward; and, in the case of the *trabeculæ*, coalesce with one another. Such an hypothesis would enable us to understand the signification of the nasopalatine canal of the Myxinoid fishes, which would be simply the interspace, or passage, between the trabeculæ (which must have originally existed if ever they were distinct sceral arches) not yet filled up; and the anomalous process on the roof of the oral cavity, which extends towards the notochordal body in the embryos of the *Vertebrata* in general, might be regarded as the remains of this passage.

On this hypothesis, six pair of inferior arches belong to the skull—namely, the trabecular and maxillo-palatine, in front of the mouth; the mandibular, the hyoidean, and two others (first and second branchial), behind it. For, as there are three cranial nerves embracing the first three visceral arches which lie behind the mouth, there must be four post-oral, cranial, visceral arches.

Supposing that the occipital segment in the brain-case answers to the hindmost, or second branchial, cranial, sceral arch, the invariable attachment of the proximal ends of the mandibular and hyoidean arches to the auditory capsule leads me to assign the parietal and the frontal segments to the maxillo-palatine and trabecular visceral arches. And thus the ossifications of the auditory capsule, bone, are left as possible representatives of the neural arches of the three anterior post-oral visceral arches.

But these speculations upon the primitive composition of the skull, however interesting, must not, as yet, be placed upon the same footing as the doctrine of its segmentation, which is simply a generalisation of anatomical facts.

The Sympathetic.—A Sympathetic Nervous System has been observed in all the *Vertebrata* except *Amphioxus* and the *Marsipobranchii*. It consists, essentially, of two longitudinal cords, placed one upon each side of the inferior part of the cranio-spinal axis. Each cord receives communicating fibres from the spinal nerves of its own side, and,

when complete, from all the cranial nerves except those of the special senses of hearing, sight, and smell—the Vidian nerves constituting the anterior terminations of the sympathetic cords. At the points of communication ganglia are developed, and the nerves which emerge from these ganglia are distributed to the muscles of the heart and vessels, and to those of the viscera. These peripheral nerves of the sympathetic system frequently present small ganglionic enlargements.

In the *Marsipobranchii*, the place of the sympathetic appears to be taken, to a great extent, by the pneumogastric; and, in *Myxine*, the two pneumogastrics unite upon the intestine, and follow it, as a single trunk, to the anus.

The Sensory Organs.—The organs of the three higher senses—Smell, Sight, and Hearing—are situated, as has been already described, in pairs, upon each side of the skull, in all vertebrate animals except the lowest fishes; and, in their earliest condition, they are alike involutions of the integument.

The *Olfactory Apparatus* acquires no higher complication than this, being either a single sac (*Amphioxus* (?) *Marsipobranchii*), or, more commonly, two, the surfaces of which are increased by plaiting, or by the development of turbinal cartilages, or bones, from the lateral portions of the ethmoid. Upon these, nervous filaments arising from the olfactory lobe of the brain are distributed. The cavities of the olfactory sacs may be placed in communication with that of the mouth by the nasal passages; or, as in the great majority of fishes, they may have only an external aperture, or apertures.

In Reptiles, Birds, and Mammals, a peculiar *nasal gland* is frequently connected with, and pours its secretion into, each olfactory chamber.

The *foramina incisiva*, left between the premaxillaries and the palatine plates of the maxillaries in *Mammalia*, are sometimes closed by the mucous membranes of the nasal and oral cavities, and sometimes not. In the latter case they

are the *canals of Stenson*, and place these two cavities in communication. Glandular diverticula of the mucous membrane, supplied with nervous filaments from both the olfactory and the fifth pair, may open into these canals. They are called, after their discoverer, the "*organs of Jacobson*."

The *Eye* is formed by the coalescence of two sets of structures, one furnished by involution of the integument, the other by an outgrowth of the brain.

The opening of the integumentary depression which is primarily formed on each side of the head in the ocular region becomes closed, and a shut sac is the result. The outer wall of this sac becomes the transparent *cornea* of the eye; the epidermis of its floor thickens, and is metamorphosed into the *crystalline lens*; the cavity fills with the *aqueous* humour. A vascular and muscular ingrowth taking place round the circumference of the sac, and, dividing its cavity into two segments, gives rise to the *iris*. The integument around the cornea, growing out into a fold above and below, results in the formation of the eyelids, and the segregation of the integument which they inclose, as the soft and vascular *conjunctiva*. The pouch of the conjunctiva very generally communicates, by the *lachrymal duct*, with the cavity of the nose. It may be raised, on its inner side, into a broad fold, the *nictitating membrane*, moved by a proper muscle or muscles. Special glands—the *lachrymal* externally, and the *Harderian* on the inner side of the eyeball—may be developed in connection with, and pour their secretion on to, the conjunctival mucous membrane.

The posterior chamber of the eye has a totally distinct origin. Very early, that part of the anterior cerebral vesicle which eventually becomes the vesicle of the third ventricle, throws out a diverticulum, broad at its outer, and narrow at its inner end, which applies itself to the base of the integumentary sac. The posterior, or outer, wall of the diverticulum then becomes, as it were, thrust in, and forced towards the opposite wall, by an ingrowth of the adjacent

connective tissue; so that the primitive cavity of the diverticulum, which, of course, communicates freely with that of the anterior cerebral vesicle, is obliterated. The broad end of the diverticulum acquiring a spheroidal shape, while its pedicle narrows and elongates, the latter becomes the optic nerve, while the former, surrounding itself with a strong fibrous *sclerotic* coat, remains as the posterior chamber of the eye. The double envelope, resulting from the folding of the wall of the cerebral optic vesicle upon itself, gives rise to the *retina* and the *choroid* coat: the plug, or ingrowth of connective tissue, gelatinises and passes into the *vitreous humour*, the cleft by which it entered becoming obliterated.

Even in the higher *Vertebrata* the optic nerve is, at first, connected exclusively with the vesicle of the third ventricle, and makes no decussation with its fellow. But by degrees the roots of origin of each nerve extend over to the opposite side of the brain, and round the thalamus, to the mesencephalon on that side, and the trunks of the two nerves become intermixed below the third ventricle, in a close and complicated manner, to form a *chiasma*.

In *Amphioxus* and *Myxine*, the eyes are very imperfectly developed, appearing to consist of little more than a rudimentary lens imbedded in the pigment, which encloses the termination of the optic nerve; and in *Myxine*, this rudimentary eye is hidden by muscles and integument. It appears doubtful whether in these fishes, and in the Lampreys, the eye is developed in the same way as in other *Vertebrata*.

In all other *Vertebrata*, the eyes have the typical structure, though sometimes, as in the Blind-fish (*Amblyopsis*) and the Mole, they have no functional importance. In the *Ichthyopsida* and *Sauropsida*, but not in *Mammalia*, the sclerotic is often partially ossified, the ossification usually forming a ring around its anterior moiety. It becomes enormously thickened in the *Cetacea*.

Except in *Amphioxus* and the *Myxinoid* fishes, the eyeball is moved by six muscles; of these, four, proceeding from the interior of the orbit to the periphery of the eye-

ball, and surrounding the optic nerve, are termed superior, inferior, internal, and external *recti*. The other two are connected with the upper and the lower margins of the orbit respectively, and pass thence to the outer side of the bulb. These are the *superior* and the *inferior obliqui*. In many Reptiles and Mammals a continuous funnel-shaped sheet of muscle, the *musculus choanoides*, lies within the four *recti*, and is attached to the circumference of the posterior moiety of the ball of the eye. It would appear, from the distribution of the nerves, which has already been described, that the *musculus choanoides*, the external *rectus*, and the nictitating muscle, constitute a group of eye-muscles morphologically distinct from the other three *recti*, the *obliqui*, and the *levator palpebræ superioris*. In many Reptiles, and in the higher *Vertebrata*, the eyelids are closed by circular muscular fibres, constituting an *orbicularis palpebrarum*, and are separated by straight fibres proceeding from the back of the orbit, usually to the upper eyelid only, as the *levator palpebræ superioris*; but sometimes to both lids, when the lower muscle is a *depressor palpebræ inferioris*.

The Harderian and lachrymal glands are not found in fishes; but the former is met with in the *Batrachia*, and both are of common occurrence in the *Sauropsida* and *Mammalia*.

In *Lacertilia*, *Crocodilia*, *Aves*, and many Fishes, a peculiar vascular membrane, covered with pigment, like the choroid, projects from near the entrance of the optic nerve, on the outer side of the globe of the eye, into the vitreous humour, and usually becomes connected with the capsule of the lens. This is the *pecten*, or *marsupium*.

The Ear.—The first rudiment of the internal ear is an involution of the integument into a small sac, which is situated on each side of the posterior cerebral vesicle, just above the end of the second visceral cleft. The mouth of the involution soon closes, and a shut sac results. The sac enlarges, and, by a remarkable series of changes, its upper part becomes (ordinarily) converted into three *semicircular*

canals—the *anterior* and *posterior vertical*, and the *external* or *horizontal canals* of the *membranous labyrinth*. The body of the sac remains, for the most part, as the *vestibule*; but a cæcal process, which eventually becomes shut off from the vestibule, is given off downwards and inwards, towards the base of the skull, and is the rudiment of the *scala media* of the *cochlea*. This may be called the *membranous cochlea*.

In the anomalous vertebrate, *Amphioxus*, no ear has yet been discovered. The Hag (*Myxine*) has only one, and in the Lampreys (*Petromyzon*) there are only two, semicircular canals; but, in fishes in general, all three are developed, and it is a question whether the cochlea is not also represented.

In fishes, the periotic cartilage and its ossifications inclose this membranous labyrinth, externally, and present no merely membranous gaps, or *fenestræ*, towards the first visceral cleft, or the space which represents it.

But in higher *Vertebrata* (*Amphibia*, *Sauropsida*, *Mammalia*), in which the membranous labyrinth is always inclosed within a complete bony periotic capsule, the outer wall of this capsule invariably remains unossified over one or two small oval areas, which consequently appear like windows with membranous panes, and are termed the *fenestra ovalis* and the *fenestra rotunda*.

The *fenestra ovalis* is situated in that part of the periotic mass which bounds the chamber containing the membranous vestibule externally; and it is always found that when both the pro-otic and the opisthotic bones exist, they contribute nearly equal shares to the formation of its boundaries. In fact, the *fenestra ovalis* is situated in the line of junction of these two bones. The *fenestra rotunda*, on the other hand, is below the *fenestra ovalis*, and lies altogether in the opisthotic. It forms part of the outer wall of the cavity in which the membranous cochlea is lodged.

In the *Sauropsida* and *Mammalia*, this membranous cochlea, become flattened and bandlike, and its communication with the vestibule obliterated, is lodged in a conical cavity, in such a manner as to divide that cavity into two

portions, called *scalæ*, which only communicate at their apices. The base of the one scala, called *scala vestibuli*, opens into the cavity which contains the membranous vestibule: that of the other, *scala tympani*, abuts against, and is as it were stopped by, the membrane of the fenestra rotunda. The cavity of the membranous cochlea stretched between, and helping to divide, these two *scalæ*, is called the *scala media*.

In Reptiles, Birds, and Ornithodelphous Mammals, the cochlea is only slightly bent or twisted upon itself. But, in the higher *Mammalia*, it becomes coiled in a flat or conical spiral of one-and-a-half (*Cetacea*, *Erinaceus*) to five (*Carlo-genys Paca*) turns.

The membranous labyrinth is filled with a clear fluid, the *endolymph*, and usually contains otolithes of various kinds. Between the membranous labyrinth and the walls of the cavity of the periotic mass in which it is contained, lies another clear fluid, the *perilymph*, which extends thence into the *scalæ vestibuli* and *tympani*.

In all animals which possess a *fenestra ovalis*, its membrane gives attachment to a disc, whence an ossified rod, or arch, proceeds. Where the former structure obtains, as in Birds, most Reptiles, and some *Amphibia*, the bone is commonly called *columella auris*; when the latter, as in most Mammals, *stapes*. But there is really no difference of importance between *stapes* and *columella*, and it is advisable to use the former name for the bone under all its forms.

In the majority of *Vertebrata* of higher organization than fishes, the first visceral cleft does not become wholly obliterated, but its upper part remains as a transversely elongated cavity, by means of which the pharynx would be placed in communication with the exterior, were it not that the opposite sides of the canal grow together into a membranous partition—the *membrana tympani*. So much of the canal as lies external to this is the external *auditory meatus*; while what lies internal to it, is the *tympanum*, or drum of the ear, and the *Eustachian tube*, which places the *tympanum* in communication with the pharynx. While the outer

wall of the tympanum is the tympanic membrane, its inner wall is the periotic mass with its *fenestræ*; and, in all *Vertebrata* below *Mammalia*, the outer end of the *stapes* is either free, or, more commonly, is fixed to the tympanic membrane, and thus the latter and the membrane of the *fenestra ovalis* become mechanically connected. In all these animals the mandible is connected with the skull by the intermediation of an *os quadratum*.

But, in the *Mammalia*, the mandible is articulated directly with the squamosal, and the *quadratum* is converted into one of the so-called *ossicula auditûs*, and named the *malleus*. The malleus becomes attached to the *membrana tympani*, by a special process; while its other extremity, which was continuous with Meckel's cartilage in the embryo, is converted into the *processus gracilis*, or *Folianus*, and lies between the tympanic, the squamosal, and the periotic bones.

In the singular lizard *Sphenodon* (A, Fig. 24), the anterior cornu of the hyoid is continuous with the distal end of the *stapes*, and the latter sends a cartilaginous process upwards, which passes into the wall of the periotic capsule, just behind the proximal end of the *os quadratum*. Thus the *stapes* stands out at right angles to the hyoid cornu, and the latter becomes divisible into a *supra-stapedial* part, and a part which lies below the *stapes*, and answers to the styloid process, or *stylohyal*, of the *Mammalia*. The supra-stapedial part is represented by cartilage, or ligament, in other *Sauropsida*, but seems not to ossify. In the *Mammalia* (B, Fig. 24) the supra-stapedial part ossifies, becomes the *incus*, and its proximal end is usually articulated by a synovial joint with the *malleus* (= *quadratum*). A distinct ossification, the *os orbiculare*, usually arises at that part of the hyoidean cartilage in which the *stapes* and the *incus* unite. That part of the hyoidean cartilage which is converted into the styloid process is generally connected with the *orbiculare* by muscular fibres, which constitute the *stapedius* muscle. On the other hand, the posterior, or short process of the *incus*, is connected by ligament with that part of the periotic mass into which the styloid process is directly continued, and it

is hard to say whether the styloid part of the hyoid is continued into the incus by these ligaments or by the *stapedius*. But, however this may be, the *malleus* and the *incus* are the proximal ends of the mandibular and hyoidean arches respectively.

In osseous fishes (C, Fig. 24), which have no fenestra ovalis or stapes, the supra-stapedial part of the hyoid becomes a large bone—the *hyomandibular*. On the other hand, the proximal extremity of the quadrate cartilage atrophies, loses

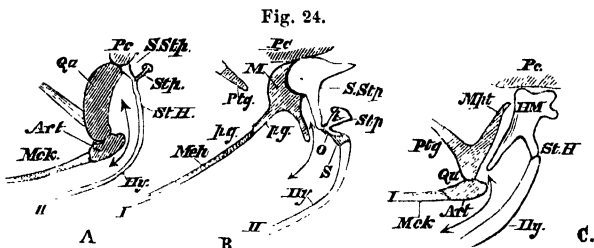


Fig. 24.—Diagram of the skeleton of the first and second visceral arches in a Lizard (A), a Mammal (B), and an Osseous Fish (C).

The skeleton of the first visceral arch is shaded, that of the second is left nearly unshaded. *I.* First visceral arch. *Mck.* Meckel's cartilage. *Art.* Articulare. *Qu.* Quadratum. *Mpt.* Metapterygoid; *M.* Malleus; *p.g.*, Processus gracilis. *II.* Second visceral arch. *Hy.* Hyoidean cornu. *St. H.* Stylohyal. *S.* Stapedius. *Stp.* Stapes. *S. Stp.* Supra-stapedial. *HM.* Hyomandibular. The arrow indicates the first visceral cleft. *Pc.* The periotic capsule. *Ptg.* The pterygoid.

its direct connection with the periotic capsule, and becomes distinctly ossified, as the *metapterygoid*. In the Sharks, even the ascending, metapterygoid, part of the quadrate, is lost.

The quadrate and supra-stapedial portions of the first and second visceral arches coalesce in the *Chimæra*, *Dipnoi*, and many *Amphibia*, into a single cartilaginous plate.

In the *Mammalia*, and to some extent in *Aves*, osseous matter is deposited in the fibrous tissue which surrounds the sides and base of the tympanic membrane, and gives rise to a special *tympanic* bone. In most *Mammalia*, ossifi-

cation extends into the sides and floor of the tympanum and external meatus; and a process of integument, chiefly derived from the second visceral arch, is converted into a *concha*, or *external ear*.

The *Organ of Taste* is the mucous membrane which covers the tongue, especially its posterior region, and probably also a part of that lining the fauces. When the sense is well developed, the mucous membrane is raised into numerous papillæ of various forms, and is well supplied with filaments from the glossopharyngeal nerve.

The sense of *Touch* is diffused over the integument and over the mucous membrane of the buccal cavity, which is, strictly speaking, a part of the integument.

As special organs of touch in the higher *Vertebrata*, the nervous papillæ, containing "*tactile corpuscles*," and the long facial hairs, the papillæ of which are well supplied with nerves, termed *vibrissæ*, may be mentioned.

In most, if not all Fishes, the integument of the body and of the head contains a series of sacs, or canals, usually disposed symmetrically on each side of the middle line, and filled with a clear gelatinous substance. The walls of the sacs, or canals, are abundantly supplied with nerves, and the terminations of the latter enter rounded papillæ, which project into the gelatinous contents. These sensory organs are known as the "*organs of the lateral line*," or "*mucous canals*;" and they were formerly supposed to be the secretory glands of the slimy matter which coats the bodies of fishes, and which is really modified epidermis.

The Alimentary Canal.—This part of vertebrate organization always exhibits a differentiation into mouth, pharynx, œsophagus, stomach, and intestine; and the last has always a median, or nearly median, aperture on the ventral surface of the body. It may open by itself; or into a *cloaca*, or chamber common to it, the urinary, and the genital organs.

The intestine is generally distinguishable into *small* and *large*; and, at the junction of the two, one or two *cæca* are frequently developed from the former.

The stomach and intestine are invested by a peritoneal membrane, and connected, by *mesogastric* and *mesenteric* folds of that membrane, with the median dorsal wall of the abdominal cavity. Glands appertaining to the lymphatic system frequently abound in the mesenteric folds, and a highly vascular gland of this system, the *spleen*, is always (except in *Amphioxus*, *Myxine*, and the *Leptocephalidæ*) developed in close proximity to the stomach. A *pancreatic* gland very generally pours its secretion into the anterior end of the intestine. *Salivary glands* very commonly open into the mouth; and, in the higher *Vertebrata*, *anal glands* are not unusually developed in connection with the termination of the rectum.

The structures connected with the alimentary canal of vertebrate animals, which are most characteristic and peculiar, are the liver and the teeth.

The Liver.—In invertebrate animals this organ is always ultimately resolvable into cæcal tubes, the ends of the hepatic ducts, which are lined with an epithelium, and not reticulated; and it has no receptacle for the bile. In most *Vertebrata* the ends of the hepatic ducts have not been satisfactorily traced, nor is it certain that the immense proportional mass of hepatic corpuscles is contained in tubes continuous with them: if such be the case, the tubes must be reticulated. The ducts of the vertebrate liver very frequently pour the bile, directly or indirectly, into a receptacle, the *gall-bladder*. *Amphioxus* stands alone among vertebrated animals, in having a cæcal diverticulum of the intestine for a liver.

The Teeth.—Teeth, in *Mollusca* and *Annulosa*, are always “*ecderonic*,” cuticular, or epithelial structures. In *Vertebrata* true teeth are invariably “*enderonic*,” or developed, not from the epithelium of the mucous membrane of the alimentary canal, but from a layer between this and the vascular deep substance of the enderon, which answers to the dermis in the integument. The horny “teeth” of the Lampreys, and of *Ornithorhynchus*, appear to be *ecderonic*

structures, homologous with the "baleen" of the *Cetacea*, with the palatal plates of the *Sirenia*, or the beaks of Birds and Reptiles, and not with true teeth.

The dense calcified tissue called *dentine*, characterised by the close-set parallel tubuli which radiate through it, branching as they go, constitutes the chief mass of true teeth; but the dentine may be coated with ordinary bony tissue, which then receives the name of *cementum*, and its crown may be capped with imperforate, prismatically fibrous, *enamel*.

The teeth are moulded upon papillæ of the mucous membrane, which may be exposed, but are more usually sunk in a fold or pit, the roof of which may close in so as to form a *dental sac*. And there may be one set of teeth, or several; the sacs of the new teeth, in the latter case, being developed either as diverticula of the old ones, or independently of them.

In the majority of the *Mammalia* the teeth are limited in number, as well as definite in their forms and their mode of succession. There are two sets of teeth, forming a first, *deciduous*, or *milk dentition*, and a second, or *permanent dentition*. The deciduous dentition, when most completely developed, consists of *incisor*, *canine*, and *molar* teeth. The incisors are distinguished from the rest by the lodgment of the upper set in the premaxillæ, and the correspondence of the lower set with the upper. Their number and form vary. The distinction between canines and molars is one of form and position in regard to the remaining teeth; the most anterior of the teeth behind the premaxillo-maxillary suture, if it is sharp and projecting, receiving the name of canine. There are never more than four canines. The other teeth are molars, and ordinarily do not exceed four upon each side, above and below. What is called a *dental formula* is a convenient combination of letters and figures for making the number and disposition of the teeth obvious. Thus, let *di*, *dc*, *dm* represent, respectively, the deciduous, or milk set of incisors, canines, and molars. Then, by placing after each of these symbols figures arranged so as to show the number of the

teeth of the kind symbolised, on each side of each jaw, we shall have the dental formula of a given animal. The dental formula of a child over two years of age is thus—

i. $\frac{2 \cdot 2}{2 \cdot 2}$ dc. $\frac{1-1}{1-1}$ dm. $\frac{2 \cdot 2}{2 \cdot 2} = 20$: which means that the child should have two incisors, one canine, and two molars on each side of each jaw.

The neck of the sac of each deciduous tooth gives off a diverticulum, in which one of the permanent teeth is developed; as it grows, it causes the absorption of the fang of the corresponding deciduous tooth, which thus becomes shed, and is replaced from below by the permanent tooth. The same letters, but without the prefix *d*, are used for the permanent incisors and canines; but the permanent teeth, which replace the deciduous molars, are called *premolars*, and have the symbol *pm*. Furthermore, three or, it may be, four permanent grinding teeth, on each side of each jaw, are developed altogether behind the milk molars, and thus come into place without replacing any other tooth from below. These are called *molars*, and have the symbol *m*. Thus the formula of the permanent dentition in Man is written:

$\frac{2 \cdot 2}{2 \cdot 2}$ c. $\frac{1-1}{1-1}$ pm. $\frac{2 \cdot 2}{2 \cdot 2}$ m. $\frac{3 \cdot 3}{3 \cdot 3} = 32$; there being two incisors, one canine, two premolars, and three molars on each side above and below. It is a rule of very general application among the *Mammalia*, that the most anterior molar comes into place and use before the deciduous molars are shed. Hence, when the hindermost premolar, which immediately precedes the first molar, comes into use by the shedding of the last milk molar, the crown of the first molar is already a little ground down; and this excess of wear of the first molar over the adjacent premolar long remains obvious. The fact that, in the permanent dentition, the last premolar is less worn than the first molar which immediately follows it, is often a valuable aid in distinguishing the premolar from the molar series.

No vertebrate animal has teeth in any part of the alimentary canal save the mouth and pharynx—except a

snake (*Rachiodon*), which has a series of what must be termed teeth, formed by the projection of the inferior spinous processes of numerous anterior vertebræ into the œsophagus. And, in the highest *Vertebrata*, teeth are confined to the premaxillæ, maxillæ, and mandible.

The Circulatory Organs.—The heart of the vertebrate embryo is at first a simple tube, the anterior end of which passes into a cardiac aortic trunk, while the posterior end is continuous with the great veins which bring back blood from the umbilical vesicle—the *omphalomesenteric veins*.

The *cardiac aorta* immediately divides into two branches, each of which ascends, in the first visceral arch, in the form of a forwardly convex *aortic arch*, to the under side of the rudimentary spinal column, and then runs, parallel with its fellow, to the hinder part of the body, as a *primitive subvertebral aorta*. The two primitive aortæ very soon coalesce throughout the greater part of their length into one trunk, the *definitive subvertebral aorta*; but the aortic arches, separated by the alimentary tract, remain distinct. Additional arterial trunks, to the number of four in the higher *Vertebrata*, and more in the lower, are successively developed, behind the first, in the other visceral arches, and further connect the cardiac and subvertebral aortæ.

In the permanently branchiate *Vertebrata*, the majority of these aortic arches persist, giving off vessels to the branchial tufts, and becoming converted into afferent and efferent trunks, which carry the blood to and take it from these tufts. (Fig. 25, A, B, C, D, E.)

In the higher *Amphibia*, which, though branchiate in the young state, become entirely air-breathers in the adult condition, such as the *Batrachia* (Fig. 25, F) and *Cæcilia*, the permeable aortic arches are reduced to two (the middle pair of the three which supply the external gills, and the fourth pair of embryonic aortic arches) by the obliteration of the cavities of the dorsal ends of the others. Of the posterior arches, the remains of the fifth and sixth become the trunks which give off the pulmonary arteries, and, in the *Batrachia*,

Fig. 25.

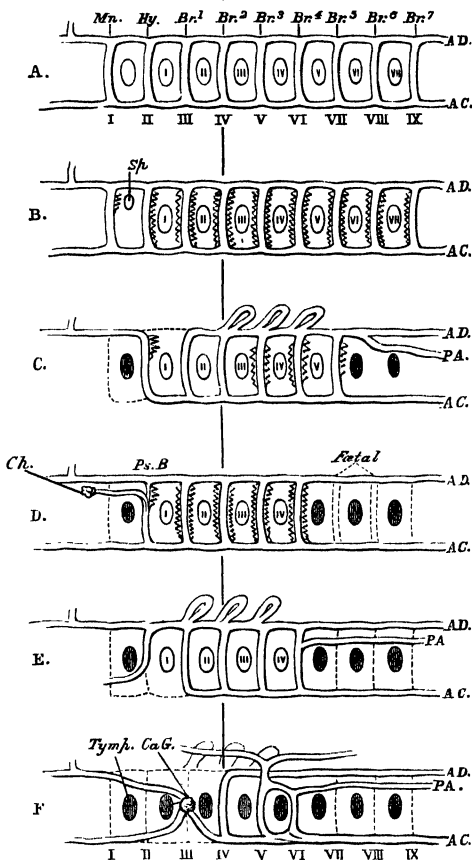


Fig. 25.—A diagram intended to show the manner in which the aortic arches become modified in the series of the *Vertebrata*.

A. A hypothetically perfect series of aortic arches, corresponding with the nine postoral visceral arches, of which evidence is to be found in some Sharks and *Marsipobranchii*. A.C. Cardiac aorta; A.D. Dorsal

or subvertebral aorta. 1.—ix. the aortic arches, corresponding with *Mn.*, the mandibular; *Hy.*, the hyoidean, and *Br.* 1—*Br.* 7, the seven branchial visceral arches. 1. II. III. IV. V. VI. VII., the seven branchial clefts. The first visceral cleft is left unnumbered, and one must be added to the number of each branchial cleft to give its number in the series of visceral clefts.

B. Hypothetical diagram of the aortic arches in the Shark *Heptanchus*, which has seven branchial clefts. *Sp.* The remains of the first visceral cleft as the spiracle. Branchiæ are developed on all the arches.

C. *Lepidosiren*.—The first arch has disappeared as such, and the first visceral cleft is obliterated. Internal branchiæ are developed in connection with the second, fifth, sixth, and seventh aortic arches; external branchiæ in connection with the fourth, fifth, and sixth. *PA.* the pulmonary artery. The posterior two visceral clefts are obliterated.

D. A Teleostean Fish.—The first aortic arch and first visceral cleft are obliterated, as before. The second aortic arch bears the pseudo-branchia (*Ps.B.*), whence issues the ophthalmic artery, to terminate in the choroid gland (*Ch.*) The next four arches bear gills. The seventh and eighth arches have been observed in the embryo, but not the ninth, and the included clefts are absent in the adult.

E. The Axolotl (*Siredon*), a perennibranchiate amphibian. The third, fourth, fifth, and sixth aortic arches, and the anterior four branchial clefts, persist. The first visceral cleft is obliterated.

F. The Frog.—The three anterior aortic arches are obliterated in the adult. The place of the third, which is connected with the anterior external gill in the Tadpole, is occupied by the common carotid and the *rete mirabile* (carotid gland, *Ca.G.*) which terminates it. The fourth pair of aortic arches persist. The fifth and sixth pair lose their connections with the subvertebral aortic trunk, and become the roots of the cutaneous and pulmonary arteries. The first visceral cleft becomes the tympanum, but all the others are obliterated in the adult.

cutaneous branches. The anterior, or third, primitive aortic arch becomes the common carotid trunk, and ends in the *carotid gland*, whence the internal and external carotids arise. In those *Vertebrata* which never possess gills, the arches become reduced either to two pair, as in some *Lacertilia*; or to one pair, as in other *Reptilia*; or to a single arch, as in *Aves* and *Mammalia*. The aortic arches thus retained are, in the Lizards in question, the third and the fourth pairs in order from before backwards; but the fourth pair only, in other Reptiles; in Birds, the right arch only of the fourth pair; and in Mammals, the left arch only of the fourth pair. The fifth pair of arches give off the pulmonary arteries, the so-called "*ductus arteriosus*" repre-

...nting the remains of the primitive connection of these
...ches with the fourth pair and the subvertebral aorta.
he dorsal ends of the first, second, and third arches become
oliterated; but their cardiac ends, and the branches which
ey give off, become the arteries of the head and upper
remities.

The embryonic aorta gives off *omphalomeseraic* branches (Fig. 26, *o*) to the umbilical vesicle; and ends, at first, in the *pyogastric* arteries (which are distributed to the allantois in the abranchiate *Vertebrata*), and a median caudal continuation. The blood from the umbilical vesicle is brought back, as before mentioned, by the omphalomeseraic veins (Fig. 26, *o'*), which unite in a dilatation close to the head; the dilatation (*sinus venosus*) receives, on each side, a short transverse venous trunk, the *ductus Cuvieri* (Fig. 26, *DC.*), which is itself formed, upon each side, by the junction of the *anterior* and *posterior cardinal veins*, which run backwards and forwards, parallel with the spine, and bring back the blood of the head and of the trunk.

The blood of the allantois is returned by the *umbilical vein*, or veins (Fig. 26, *u'*), which are formed in the anterior wall of the abdomen, and open into the venous sinus before mentioned. The blood of the posterior extremities and kidneys is, after a while, brought to the same point by a special median vein, the *vena cava inferior* (Fig. 26, *cv.*).

The development of the liver effects the first great change in the arrangements now described. It, as it were, interrupts the course of the omphalomeseraic vein, which is not only the vein of the umbilical sac but also that of the intestine, and converts it into a meshwork of canals, which communicate, on one side, with the cardiac part of the vein, and, on the other side, with its intestinal part. The latter is thus converted into the *vena portæ* (Fig. 26, *vp.*), distributing the blood of the stomach and intestines to the liver; while the former becomes the *hepatic vein* (*vh*), carrying the hepatic blood to the inferior cava, and thence to the heart.

coalescence of the efferent veins of the kidneys and reproductive organs, and does not always receive the whole of the hepatic veins—more or fewer of the latter opening independently into the *sinus venosus*.

The blood which leaves the kidneys by its efferent veins is supplied, not only by the renal arteries, but by the veins of the caudal region, and of the hinder extremities, which branch out like a *vena portæ* in the substance of the kidneys. This renal portal system is less developed in *Reptilia* than in *Amphibia*. All the blood of the posterior extremities and caudal region does not traverse the kidneys, however, more or less of it being led away by great branches of the iliac veins, which run along the anterior wall of the abdominal cavity, either as two trunks, or united into one. These *venæ abdominales anteriores* are eventually distributed to the liver, along with the branches of the proper *venæ portæ*.

In *Birds*, the *sinus venosus* is not distinct from the right auricle, and there are two anterior *venæ cavæ*. The *vena cava inferior* arises, as in *Mammals*, by the union of the two common iliac veins. It receives both the right and the left hepatic veins, and, in addition, the anterior abdominal vein no longer enters the portal system, but passes up the anterior wall of the abdomen and through the hepatic fissure to join the inferior cava.

The caudal and pelvic veins unite into three principal trunks, of which one is median and two are lateral. The median enters into the portal system. The lateral branches pass along and through the kidney, receiving veins from it, but giving none to it; and eventually, after receiving the ischiatic veins, unite with the crural veins to form the common iliacs. Thus there is no renal portal system in birds.

In *Mammalia*, the *sinus venosus* is not distinct from the right auricle. The *anterior cavæ* are frequently reduced to one, the right. The *vena cava inferior* commences in the caudal region, and receives all the blood of the posterior moiety of the body, except so much as is carried away by the azygous veins. The anterior abdominal veins are repre-

presented only during foetal life, by the umbilical vein or veins. The efferent veins of the kidneys open directly into the trunk of the inferior vena cava, and the portal vein is composed exclusively of radicles proceeding from the chylipoietic viscera.

Many of the veins of *Amphioxus*, the portal vein of *Myxine*, dilatations of the caudal vein in the Eel, the venæ cavæ and the iliac and axillary veins of many *Amphibia*, the veins of the wing of Bats, possess a rhythmical contractility, which, in combination with the disposition of their valves, assists the circulation of the blood.

In *Vertebrata* of all classes, and in very diverse parts of the body, both veins and arteries occasionally break up into numerous branches of nearly equal size, which may or may not unite again into larger trunks. These are called *retia mirabilia*.

Modifications of the Heart.—Great changes go on in the structure of the heart, *pari passu* with the modifications of the rest of the circulatory system, in the development of the highest *Vertebrata*. The primitively simple tube becomes bent upon itself, and divided from before backwards into an aortic, or *ventricular*, and a venous, or *auricular*, portion. A median septum then grows inward, dividing the auricular and ventricular chambers into two, so that a right auricle and right ventricle become separated from a left auricle and left ventricle. A similar longitudinal division is effected in the cardiac aorta. The septa are so disposed in the auriculo-ventricular chamber that the right auricle communicates with the venous sac and the trunks of the visceral and body veins, while only the veins from the lungs enter into the left auricle. And the cardiac aorta is so divided that the left ventricle communicates with the chief aortic trunk, the right with the pulmonary artery. Valves are developed at the auriculo-ventricular apertures and at the origins of the aortic and pulmonary trunks, and thus the course of the circulation is determined. The septum between the auricles remains incomplete for a

much longer period than that between the ventricles—and the aperture by which the auricles communicate is called the *foramen ovale*.

In the adult state of *Aves* and *Mammalia*, the *foramen ovale* is closed; there is no direct communication between the arterial and venous cavities or trunks; there is only one aortic arch; and the pulmonary artery alone arises from the right ventricle. In the *Crocodylia*, the auricles and ventricles of opposite sides are completely separate; but there are two aortic arches, and one of these, the left, arises from the right ventricle along with the pulmonary artery. In all *Reptilia*, except *Crocodyles*, there is but one ventricular cavity, though it may be divided more or less distinctly into a *cavum venosum* and a *cavum arteriosum*. The auricles are completely separated (except in some *Chelonina*), and the blood of the left auricle flows directly into the *cavum arteriosum*, while that of the right passes immediately into the *cavum venosum*. The aortic arches and the pulmonary artery all arise from the *cavum venosum* (or a special subdivision of that cavity called the *cavum pulmonale*); the ostium of the pulmonary artery being farthest from, and that of the right aortic arch nearest to, the *cavum arteriosum*.

In all *Amphibia*, the spongy interior of the ventricle is undivided, and the heart is trilocular, though the auricular septum is sometimes small and incomplete. In all *Pisces*, except *Lepidosiren*, there is no auricular septum. In *Amphioxus* the heart remains in its primitive state of a simple, contractile, undivided tube.

In the *Ganoidei*, the *Elasmobranchii*, and the *Amphibia*, the walls of the enlarged commencement of the cardiac aorta, called the *bulbus aortæ*, contain striped muscular fibre, and are rhythmically contractile.

The *Ganoidei* and *Elasmobranchii* possess, not merely the ordinary semilunar valves, at the junction between the ventricle and the cardiac aorta, but a variable number of additional valves, set, in transverse rows, upon the inner wall of the aortic bulh.

The change of position which the heart and the great

Vessels of the highest *Vertebrata* undergo during embryonic life is exceedingly remarkable, and is repeated as we ascend in the series of adult vertebrates.

At first, the heart of a mammal lies under the middle of the head, immediately behind the first visceral arches, in which the first pair of aortic arches ascend. As the other pairs of aortic arches are developed the heart moves backward; but the fourth pair of aortic arches, by the modification of one of which the persistent aorta is formed, lies, at first, no farther back than the occipital region of the skull, to which, as we have seen above, the fourth pair of visceral arches belongs. As the two pairs of cornua of the hyoid belong to the second and the third visceral arches, the larynx is probably developed within the region of the fourth and fifth visceral arches; hence, the branches of the pneumogastric, with which it is supplied, must, originally, pass directly to their destination. But, as development proceeds, the aortic arches and the heart become altogether detached from the visceral arches and move back, until, at length, they are lodged deep in the thorax. Hence the elongation of the carotid arteries; hence also, as the larynx remains relatively stationary, the singular course, in the adult, of that branch of the pneumogastric, the *recurrent laryngeal*, which primitively passed to the laryngeal region behind the fourth aortic arch, and consequently becomes drawn out into a long loop—the middle of it being, as it were, pulled back, by the retrogression of the aortic arch into the thorax.

The Blood Corpuscles.—Corpuscles are contained in the blood of all *Vertebrata*. In *Amphioxus* they are all of one kind, colourless and nucleated. The genus *Leptocephalus*, among the *Teleostei*, is said to possess the same peculiarity; but in all other known *Vertebrata*, the blood contains corpuscles of two kinds.

In *Ichthyopsida* and *Sauropsida*, both kinds are nucleated; but one set are colourless, and exhibit amœboid movements, while the others are red, and do not display

contractility. Except in the *Marsipobranchii*, which have round blood-corpuscles, the red corpuscles are oval. They attain a larger size in the perennibranchiate *Amphibia* than in any other Vertebrates.

In *Mammalia*, the blood-corpuscles are also of two kinds, colourless and red, the colourless possessing, and the red being devoid of, nuclei. It is but very rarely that a nucleated corpuscle, with a red colour especially developed about the nucleus, is seen in Mammalian blood; but such cases do occur; and, from this and other circumstances, it is probable that the Mammalian red corpuscle is a free-coloured nucleus.

The colourless corpuscles of *Mammalia* are spheroidal, and exhibit amœboid movements; the red corpuscles are flattened, usually circular, but sometimes oval (*Camelidæ*) discs, devoid of contractility.

The Lymphatic System.—This system of vessels consists, chiefly, of one or two principal trunks, the *thoracic duct*, or *ducts*, which underlie the vertebral column, and communicate, anteriorly, with the superior venæ cavæ, or with the veins which open into them.

From these trunks, branches are given off, which ramify through all parts of the body, except the bulb of the eye, the cartilages, and the bones. In the higher *Vertebrata*, the larger branches are like small veins, provided with definite coats, and with valves opening towards the larger trunks, while their terminal ramifications form a capillary network; but, in the lower Vertebrates, the lymphatic channels assume the form of large and irregular sinuses, which not unfrequently completely surround the great vessels of the blood system.

The lymphatics open into other parts of the venous system besides the affluents of the superior cavæ. In Fishes there are, usually, two caudal lymphatic sinuses which open into the commencement of the caudal vein. In the Frog, four such sinuses communicate with the veins, two in the coccygeal, and two in the scapular, region. The walls of

these sinuses are muscular, and contract rhythmically, so that they receive the name of *Lymphatic hearts*. The posterior pair of these hearts, or non-pulsating sinuses corresponding with them, are met with in *Reptilia* and *Aves*.

Accumulations of indifferent tissue in the walls of some of the lymphatic sinuses are to be met with in Fishes; but it is only in the *Crocodylia*, among *Reptilia*, that an accumulation of such tissue, traversed by lymphatic canals and bloodvessels, is apparent, as a *Lymphatic gland*, in the mesentery. Birds possess a few glands in the cervical region; and, in *Mammalia*, they are found, not only in the mesentery, but in many parts of the body.

The *Spleen* is substantially a lymphatic gland. The *Thymus*—a glandular mass with an internal cavity, but devoid of any duct—which is found in all *Vertebrata* except *Amphioxus*, appears to belong to the same category. It is developed in the neighbourhood of the primitive aortic arches, and is double in most of the lower *Vertebrata*, but single in *Mammalia*.

The nature of two other “ductless glands,” the *Thyroid gland* and the *Suprarenal capsules*, which occur very widely among the *Vertebrata*, is by no means well understood.

The thyroid gland is a single or multiple organ, formed of closed follicles, and is situated near the root of the aorta, or the great lingual, or cervical, vessels which issue from it.

The suprarenal capsules are follicular organs, often abundantly supplied with nerves, which appear to occur in Fishes, and are very constant in the higher *Vertebrata*, at the anterior ends of the true kidneys.

The *Lymph Corpuscles*, which float in the plasma of the lymphatic fluid, always resemble the colourless corpuscles of the blood.

The Respiratory Organs.—Vertebrated animals may possess either *branchiæ* for breathing the air contained in water, or *lungs* for atmospheric respiration; or they may possess both kinds of respiratory organs in combination.

Except in *Amphioxus*, the *branchiæ* are always lamellar, or filamentous, appendages of more or fewer of the visceral arches; being sometimes developed only on the proper branchial arches, sometimes extending to the hyoidean arch, or (as would appear to be the case with the spiracular branchiæ of some fishes) even to the mandibular arch. The branchiæ are always supplied with blood by the divisions of the cardiac aorta; and the different trunks which carry the aerated blood away, unite to form the subvertebral aorta, so that all vertebrated animals with exclusively branchial respiration have the heart filled with venous blood.

In the early life of many branchiated *Vertebrata*, the branchiæ project freely from the visceral arches to which they are attached, on the exterior of the body; and in some *Amphibia*, such as the Axolotl (*Siredon*), they retain their form of *external* plumelike appendages of the neck throughout life. But in the adult life of most Fishes, and in the more advanced condition of the Tadpoles of the higher *Amphibia*, the branchiæ are *internal*, being composed of shorter processes, or ridges, which do not project beyond the outer edges of the branchial clefts; and, generally, become covered by an operculum developed from the second visceral arch.

The *lungs* of vertebrated animals are sacs, capable of being filled with air, and developed from the ventral wall of the pharynx, with which they remain connected by a shorter or longer tube, the *trachea*, the division of this for each lung being a *bronchus*. Venous blood is conveyed to them directly from the heart by the pulmonary arteries, and some* or all of the blood which they receive goes back, no less directly, to the same organ by the pulmonary veins.

The vascular distribution thus described constitutes an essential part of the definition of a lung, as many fishes possess hollow sacs filled with air; and these sacs are developed, occasionally, from the ventral, though more commonly from the dorsal, wall of the pharynx, œsophagus, or

* Generally all, but in some *Amphibia*, such as *Proteus*, part of the blood supplied to the lungs enters the general circulation.

stomach. But such air-sacs—even when they remain permanently connected with the exterior by an open passage or *pneumatic duct*—are *air-bladders*, and not lungs, because they receive their blood from the adjacent arteries of the body, and not direct from the heart, while their efferent vessels are connected only with the veins of the general circulation.

The wall of each pulmonic air-sac is at first quite simple, but it soon becomes cellular by the sacculation of its parietes. In the lower pulmonated *Vertebrata*, the sacculation is more marked near the entrance of the bronchus; and when the lung-sac is long, as in many *Amphibia* and in Snakes, the walls of the posterior end may retain the smooth condition of the embryonic lung. In *Chelonia* and *Crocodylia*, the lung is completely cellular throughout, but the bronchi do not give off branches in the lungs. In Birds, branches are given off at right angles; and, from these, secondary branches, which lie parallel with one another, and eventually anastomose. In *Mammalia*, the bronchi divide dichotomously into finer and finer bronchial tubes, which end in sacculated air-cells.

Blind air-sacs are given off from the surfaces of the lungs in the *Chamæleonidae*, and the principal bronchial tubes terminate in large air-sacs in *Aves*.

The Larynx and the Syrinx.—The trachea is commonly kept open by complete, or incomplete, rings of cartilage, and the uppermost of these undergo special modifications, which convert them into a *Larynx*, an organ which, under certain circumstances, becomes an instrument of voice.

When completely developed, the larynx presents a ring-like cartilage called *cricoid*, which lies at the summit of the trachea. With the anterior and dorsal edge of this, two *arytenoid* cartilages are moveably articulated, and a *thyroid* cartilage of a V-shape, open behind, is articulated moveably with its sides. Folds of the mucous membrane, containing elastic tissue, termed the *vocal cords*, stretch from the arytenoid cartilages to the re-entering angle of the thyroid cartilage, and between them lies a slit-like passage, the *glottis*. This is covered by a cartilage, the *epiglottis*, attached

to the re-entering angle of the thyroid, and to the base of the tongue. Folds of mucous membrane, extending from the epiglottis to the arytenoid cartilages, are the *aryepiglottic ligaments*. The inner surfaces of these end below in the *false vocal cords*, between which and the true *chordæ vocales*, lie recesses of the mucous membrane, the *ventricles* of the larynx.

The chief accessory cartilages are the *cartilages of Santorini*, attached to the summits of the arytenoid cartilages, and the *cartilages of Wrisberg*, which lie within the aryepiglottic ligaments.

Birds possess a larynx in the ordinary position; but it is another apparatus, the *lower larynx* or *syrinx*, developed either at the end of the trachea, or at the commencement of each *bronchus*, which is their great vocal organ.

The Mechanism of Respiration.—The mechanism by which the ærating medium is renewed in these different respiratory organs is very various. Among branchiated *Vertebrata*, *Amphioxus* stands alone in having ciliated branchial organs, which form a network very similar to the perforated pharyngeal wall of the Ascidians. Most Fishes breathe by taking ærated water in at the mouth, and then shutting the oral aperture, and forcing the water through the branchial clefts, when it flows over the branchial filaments.

Pulmonated *Vertebrata* which have the thoracic skeleton incomplete (as the *Amphibia*), breathe by distending their laryngeal cavity with air; and then, the mouth and nostrils being shut, pumping it, by the elevation of the hyoidean apparatus and floor of the pharynx, into the lungs. A Frog, erefore, cannot breathe properly if its mouth is kept wide open.

In most *Reptilia*, and in all *Aves* and *Mammalia*, the diaphragm and ribs are capable of moving in such a way, alternately to increase and diminish the capacity of the thoracic-abdominal cavity, and thereby to give rise to an inspiratory and expiratory flow of air.

In the *Reptilia*, the elastic lungs dilate with the inspiration; and contract with the expiratory act; but in *Aves*, air rushes through the principal bronchial passages of

he fixed and little distensible lungs, into the very dilatable and compressible air-sacs. From these the act of expiration expels it back through the principal bronchial passages to the trachea, and so out of the body.

Both in *Reptilia* (e. g. *Chelonia*) and in *Aves*, muscular fibres pass from the ribs to the surface of the lungs beneath the pleuroperitoneal membrane, and this rudimentary diaphragm acquires a very considerable development in the *Ratitæ*, or struthious birds. So far as the contraction of these fibres tends to remove the ventral from the dorsal walls of the lungs, they must assist inspiration. But this diaphragmatic inspiration remains far weaker than the sterno-costal inspiration.

Finally, in the *Mammalia*, there are two equally important respiratory pumps, the one sterno-costal, the other diaphragmatic. The *diaphragm*, though it makes its appearance in *Sauropsida*, only becomes a complete partition between the thorax and the abdomen in mammals; and as its form is such, that, in a state of rest, it is concave towards the abdominal cavity, and convex towards the thorax, the result of its contraction, and consequent flattening, necessarily is to increase the capacity of the thorax, and thus pump the air into the elastic lungs, which occupy a large part of the thoracic cavity. When the diaphragm ceases to contract, the elasticity of the lungs is sufficient to expel the air taken in.

Thus, mammals have two kinds of respiratory mechanism, either of which is efficient by itself, and may be carried on independently of the other.

The Renal Organs.—The higher *Vertebrata* are all provided with two sets of renal organs, the one existing only during the early foetal state, the other persisting throughout life.

The former are the *Wolffian bodies*, the latter the true *Kidneys*.

The Wolffian bodies make their appearance very early, on each side of the ventral aspect of the spinal region of the embryo, as small transversely-disposed tubuli, opening into

a duct which lies upon their outer side, and enters, posteriorly, into the base of the allantois, and thence into the primitive cloaca with which that structure is connected. The Wolffian duct is one of the first-formed structures in the embryo, and precedes the tubuli.

The *Kidneys* appear behind the Wolffian bodies, and, apparently, independently of them; their ducts, the *ureters*, are also distinct, but likewise terminate in the pelvic part of the allantois. Thus the urinary secretion passes into the allantois, and it is that portion of this organ which lies within the abdomen, and becomes shut off from the rest by the constriction and obliteration of the cavity of an intermediate part, and its conversion into the *urachus*, that gives rise to the *urinary bladder*. The ultimate secreting tubuli of both the Wolffian body and the kidney, are alike remarkable for ending in dilatations which embrace convoluted capillaries—the so-called *malpighian tufts*. Neither Wolffian bodies nor kidneys have been observed in *Amphioxus*. It is doubtful whether true kidneys are developed in *Ichthyopsida*, or whether the so-called kidneys of these animals are not, rather, persistent Wolffian bodies.

The Reproductive Organs.—These, in vertebrated animals, are primitively similar in both sexes, and arise on the inner side of the Wolffian bodies, and in front of the kidneys, in the abdominal cavity. In the female the organ becomes an *ovarium*. This, in some few fishes, sheds its ova as soon as they are ripened into the peritoneal cavity, whence they escape by *abdominal pores*, which place that cavity in direct communication with the exterior. In many fishes, the ovaries become tubular glands, provided with continuous ducts, which open externally, above and behind the anus. But, in all other *Vertebrata*, the ovaries are glands without continuous ducts, and which discharge their ova from sacs, the *Graafian follicles*, successively developed in their solid substance. Nevertheless, these ova do not fall into the peritoneal cavity, but are conveyed away by a special apparatus, consisting of the *Fallopian tubes*, which result from

he modification of certain embryonic structures called the *Müllerian ducts*.

The Müllerian ducts are canals which make their appearance alongside the ducts of the Wolffian bodies, but, throughout their whole extent, remain distinct from them. Their proximal ends lie close to the ovary, and become open and dilated to form the so-called *ostia*. Beyond these ostia they generally remain narrow for a space, but towards their hinder openings into the genito-urinary part of the cloaca, they commonly dilate again. In all animals but the didelphous and monodelphous *Mammalia*, the Müllerian ducts undergo no further modification of any great morphological importance; but, in the monodelphous *Mammalia*, they become united, at a short distance in front of their posterior ends; and then, the segments between the latter and the point of union, or still farther forward, coalesce into one. By this process of confluence the Müllerian ducts are primarily converted into a single *vagina* with two *uteri* opening into it; but in most of the *Monodelphia*, the two uteri also more or less completely coalesce, until both Müllerian ducts are represented by a single vagina, a single uterus, and two Fallopian tubes. The didelphous *Mammalia* have two vaginæ which may, or may not, coalesce anteriorly for a short extent; but the two uteri remain perfectly distinct. So that what takes place in them is, probably, a differentiation of each Müllerian duct into Fallopian tube, uterus, and vagina, with or without the union of the two latter, to the extent to which it is effected in the earlier stages of development in *Monodelphia*. The Wolffian ducts of the female either persist as canals, the so-called *canals of Gaertner*, which open into the vagina, or disappear altogether. Remains of the Wolffian bodies constitute the *parovaria*, observable in certain female mammals.

In the male vertebrate embryo, the *testis*, or essential reproductive organ, occupies the same position, i. e. in front of the Wolffian body, as the ovary; and, like the latter, is composed of indifferent tissue. In *Amphioxus* and in the

Mursipobranchii, this tissue appears to pass directly into spermatozoa; but, in most *Vertebrata*, it acquires a saccular

Fig. 27.

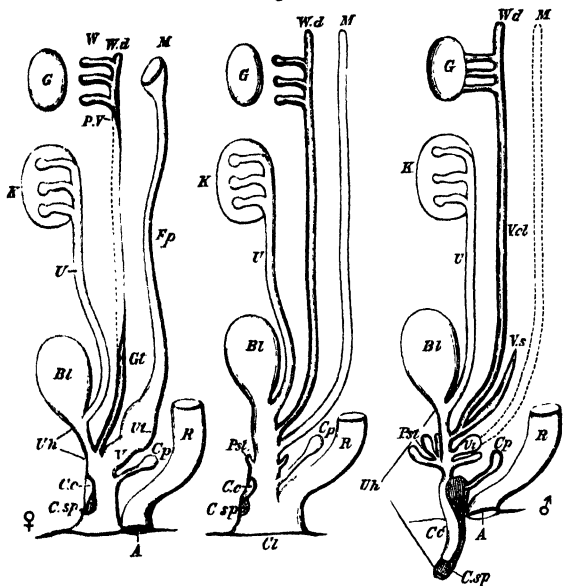


Fig. 27.—Diagram exhibiting the relations of the female (the left-hand figure, ♀), and of the male (the right-hand figure, ♂) reproductive organs to the general plan (the middle figure) of these organs in the higher *Vertebrata*.

Cl, the cloaca; *R*, the rectum; *Bl*, the urinary bladder; *U*, the ureter; *K*, the kidney; *Uh*, the urethra; *G*, the genital gland, ovary, or testis; *W*, the Wolffian body; *Wd*, the Wolffian duct; *M*, the Müllerian duct; *Pst*, prostate gland; *Cp*, Cowper's gland; *Csp*, the corpus spongiosum; *Cc*, the corpus cavernosum.

In the female, *V*, the vagina; *Ut*, the uterus; *Fp*, the Fallopian tube; *Gt*, Gaertner's duct; *P.r*, the parovarium; *A*, the anus; *Cc*, *C.sp*, the clitoris. In the male, *Csp*, *Cc*, the penis; *Ut*, the uterus masculinus; *Vs*, vesicula seminalis; *Vd*, the vas deferens.

or tubular structure, and from the epithelium of the sacs, or tubuli, the spermatozoa are developed. At first, the testis is

is completely devoid of any excretory canal as the ovary; but, in the higher vertebrates, this want is speedily supplied by the Wolffian body, certain of the tubuli of which become continuous with the *tubuli seminiferi*, and constitute the *vasa efferentia*, while the rest abort. The Wolffian duct thus becomes the *vas deferens*, or excretory duct of the testis; and its anterior end, coiling on itself, gives rise to the *epididymis*. A *vesicula seminalis* is a diverticulum of the *vas deferens*, near its posterior end, which serves as a receptacle for the semen.

If the Wolffian bodies, the genitalia, and the alimentary canal of a vertebrate embryo, communicated with the exterior by apertures having the same relative position as the organs themselves, the anus would be in front and lowest, the Wolffian apertures behind and highest, and the genital apertures would lie between the two. But the anal, genital, and urinary apertures are found thus related only among certain groups of fishes, such as the *Teleostei*. In all other *Vertebrata*, there is either a *cloaca*, or common chamber, into which the rectum, genital, and urinary organs open; or, the anus is a distinct posterior and superior aperture, and the opening of a genito-urinary sinus, common to the urinary and reproductive organs, lies in front of it, separated by a more or less considerable *perinæum*.

These conditions of adult *Vertebrata* repeat the states through which the embryo of the highest vertebrates pass. At a very early stage, an involution of the external integument gives rise to a *cloaca*, which receives the allantois, the ureters, the Wolffian and Müllerian ducts, in front, and the rectum behind. But, as development advances, the rectal division of the *cloaca* becomes shut off from the other, and opens by a separate aperture—the definitive *anus*, which thus appears to be distinct, morphologically, from the anus of an osseous fish. For a time, the anterior, or genito-urinary part of the *cloaca*, is, to a certain extent, distinct from the rectal division, though the two have a common termination; and this condition is repeated in *Aves*, and in ornithodelphous

Mammalia, where the bladder, the genital ducts, and the ureters, all open separately from the rectum into a genito-urinary sinus.

In the male sex, as development advances, this genito-urinary sinus becomes elongated, muscular, and surrounded, where the bladder passes into it, by a peculiar gland, the *prostate*. It thus becomes converted into what are termed the *fundus*, and *neck of the bladder*, with the *prostatic* and *membranous* portions of the urethra. Concomitantly with these changes, a process of the ventral wall of the cloaca makes its appearance, and is the rudiment of the intromittent organ, or *penis*. Peculiar erectile vascular tissue, developed within this body, gives rise to the median *corpus spongiosum* and the lateral *corpora cavernosa*. The penis gradually protrudes from the cloaca; and while the corpus spongiosum terminates the anterior end of it, as the *glans*, the corpora cavernosa attach themselves, posteriorly, to the *ischia*. The under, or posterior, surface of the penis is, at first, simply grooved; by degrees the two sides of the groove unite, and form a complete tube embraced by the corpus spongiosum. The *penial urethra* is the result.

Into the posterior part of this penial urethra, which is frequently dilated into the so-called *bulbus urethræ*, glands, called *Cowper's glands*, commonly pour their secretion; and the penial, membranous, and prostatic portions of the urethra (genito-urinary sinus) uniting into one tube, the male *definitive urethra* is finally formed.

In sundry birds and reptiles, the penis remains in the condition of a process of the ventral wall of the cloaca, grooved on one face. In ornithodelphous mammals the penial urethra is complete, but open behind, and distinct from the genito-urinary sinus. In the *Didelphia* the penial urethra and genito-urinary sinus are united into one tube, but the corpora cavernosa are not directly attached to the ischium.

Certain *Reptilia* possess a pair of eversible copulatory organs situated in integumentary sacs, one on each side of the cloaca, but it does not appear in what manner these

penes are morphologically related to those of the higher *Vertebrata*.

In the female sex, the homologue of a penis frequently makes its appearance, as a *clitoris*, but rarely passes beyond the stage of a grooved process with corpora cavernosa and corpus spongiosum—the former attached to the ischium, and the latter developing a glans. But, in some few mammals (*e.g.* the *Lemuridae*), the clitoris is traversed by an urethral canal.

In no vertebrated animal do the ovaries normally leave the abdominal cavity, though they commonly forsake their primitive position, and may descend into the pelvis. But, in many mammals, the testes pass out of the abdomen through the *inguinal* canal, between the inner and outer tendons of the external oblique muscle, and, covered by a fold of peritoneum, descend temporarily or permanently into a pouch of the integument—the *scrotum*. In their course they become invested with looped muscular fibres, which constitute the *cremaster*. The cremaster retracts the testis into the abdominal cavity, or towards it, when, as in the higher mammals, the inguinal canal becomes very much narrowed or altogether obliterated. In most mammals the scrotal sacs lie at the sides of, or behind, the root of the penis, but in the *Didelphia* the scrotum is suspended by a narrow neck in front of the root of the penis.

In most mammals the penis is inclosed in a sheath of integument, the *preputium*; and in many, the septum of the corpora cavernosa is ossified, and gives rise to an *os penis*.

In the female the so-called *labia majora* represent the scrotal, the *labia minora* the preputial, part of the male organ of copulation.

Organs not directly connected with reproduction, but in various modes accessory to it, are met with in many *Vertebrata*. Among these may be reckoned the integumentary pouches, in which the young are sheltered during their development in the male Pipefish (*Syngnathus*), in some female *Amphibia* (*Notodelphys*, *Pipa*), and *Marsupialia*; together with the mammary glands of the *Mammalia*.

CHAPTER III.

THE PROVINCES OF THE VERTEBRATA—THE CLASS PISCES.

THE **Vertebrata** are divisible into three primary groups or provinces: the *Ichthyopsida*, the *Sauropsida*, and the *Mammalia*.

I.—The *Ichthyopsida*

1. Have the epidermic exoskeleton either absent, or very slightly represented.

2. The spinal column may persist as a notochord with a membranous sheath, or it may exhibit various degrees of chondrification or ossification. When the vertebræ are distinct their centra have no epiphyses.

3. The skull may be incomplete and membranous, more or less cartilaginous, or osseous. When membrane bones are developed in connection with it, there is a large parasphenoid. The basisphenoid is always small, if it be not absent.

4. The occipital condyle may be absent, or single, or double. When there are two occipital condyles they belong to the ex-occipital region, and the basi-occipital region is unossified or very imperfectly ossified.

5. The mandible may be absent, or be represented only by cartilage. If membrane bones are developed in connection with it, there is usually more than one on each side. The articular element may be ossified or not, and may be connected with the skull by the intermediation of a quadrate and a hyomandibular element, or by a single fixed plate of cartilage representing both these and the pterygo-palatine arch. A stapes may be present or absent.

6. The alimentary canal may or may not terminate in a cloaca. When there is no cloaca the rectum opens in front of the urinary organs.

7. The blood-corpuscles are always nucleated, and the heart may be tubular, bilocular, or trilocular.

8. There are never fewer than two aortic arches in the adult.

9. Respiration takes place by branchiæ during part, or the whole, of life.

10. There is no thoracic diaphragm.

11. The urinary organs are permanent Wolffian bodies.

12. The cerebral hemispheres may be absent, and are never united by a corpus callosum.

13. The embryo has no amnion, and, at most, a rudimentary allantois.

14. There are no mammary glands.

II.—The **Sauropsida**

1. Almost always possess an epidermic exoskeleton in the form of scales or feathers.

2. The centra of the vertebræ are ossified, but have no terminal epiphyses.

3. The skull has a completely ossified occipital segment, and a large basisphenoid. No separate parasphenoid exists in the adult. The pro-otic is always ossified, and either remains distinct from the epiotic and opisthotic throughout life, or unites with them only after they have ankylosed with adjacent bones.

4. There is always a single, convex, occipital condyle, into which the ossified ex-occipitals and basi-occipital enter in various proportions.

5. The mandible is always present, and each ramus consists of an articular ossification, as well as of several membrane bones. The articular ossification is connected with the skull by a quadrate bone. The apparent "ankle-joint" is situated, not between the tibia and the astragalus, as in all *Mammalia*, but between the proximal and the distal divisions of the tarsus.

6. The alimentary canal terminates in a cloaca.
7. The heart is trilocular or quadrilocular. Some of the blood-corpuscles are always red, oval, and nucleated.
8. The aortic arches are usually two or more, but may be reduced to one, which then belongs to the right side.
9. Respiration is never effected by means of branchiæ, but, after birth, is performed by lungs. The bronchi do not branch dichotomously in the lungs.
10. A thoracic diaphragm may exist, but it never forms a complete partition between the thoracic and the abdominal viscera.
11. The Wolfian bodies are replaced, functionally, by permanent kidneys.
12. The cerebral hemispheres are never united by a corpus callosum.
13. The reproductive organs open into the cloaca, and the oviduct is a Fallopian tube, which presents an uterine dilatation in the lower part of its course.
14. All are oviparous, or ovoviviparous.
15. The embryo has an amnion, and a large respiratory allantois, and is developed at the expense of the massive vitellus of the egg.
16. There are no mammary glands.

III.—The **Mammalia**

1. Always possess an epidermic exoskeleton in the form of hairs.
2. The vertebrae are ossified, and (except in the *Ornithodelphia*) their centra have terminal epiphyses.
3. All the segments of the brain-case are completely ossified. No distinct parasphenoid exists in the adult. The pro-otic ossifies, and unites with the epiotic and opisthotic before these coalesce with any other bone.
4. There are always two occipital condyles, and the basioccipital is well ossified.
5. The mandible is always present, and each ramus consists (at any rate, in the adult) of a single membrane bone, which articulates with the squamosal. The quadrate bone,

and the supra-stapedial element of the hyoidean arch, are converted into a malleus and an incus, so that, with the *stapes*, there are, at fewest, three *ossicula auditus*.

6. The alimentary canal may, or may not, terminate in a cloaca. When it does not, the rectum opens behind the genito-urinary organs.

7. The heart is quadrilocular. Some of the blood-corpuscles are always red and non-nucleated.

8. There is only one aortic arch, which lies on the left side.

9. Respiration is never effected by means of branchiæ, but, after birth, is performed by lungs.

10. There is a complete diaphragm.

11. The Wolffian bodies are replaced by permanent kidneys.

12. The cerebral hemispheres are united by a corpus callosum.

13. The reproductive organs may, or may not, open into a cloaca. The oviduct is a Fallopian tube.

14. The embryo has an amnion and an allantois.

15. Mammary glands supply the young with nourishment.

The Ichthyopsida.—Class I.—PISCES.

The class of Fishes contains animals which vary so much in their grade of organization, and in their higher forms so closely approach the *Amphibia*, that it is difficult to draw up any definition which shall be at once characteristic and diagnostic of them. But they are the only vertebrated animals which possess median fins supported by fin-rays; and in which the limbs, when present, do not exhibit that division into brachium, antebrachium, and manus which is found in all other *Vertebrata*.

The presence of the peculiar integumentary organs constituting what is known as the system of mucous canals and the organs of the lateral line (*supra*, p. 86), is highly characteristic of Fishes, though these organs cannot be said to exist in the entire class.

The class PISCES is divisible into the following primary groups:—

- A. The notochord extends to the anterior end of the body. There are no skull, brain, auditory, or renal organs, such as exist in the

higher *Vertebrata*. The heart is a simple tube, and the liver is saccular. (LEPTOCARDIA. Haeckel).

I.—*Pharyngobranchii*.

B. The notochord ends behind the pituitary fossa. A skull, brain, auditory, and renal organs are developed. The heart is divided into auricular and ventricular chambers. The liver has the ordinary structure (PACHYCARDIA. Hck.).

a. The nasal sac is single, and has a median external aperture. Neither mandibles nor limb arches are developed (*Monorhina*. Hck.).

II.—*Marsipobranchii*.

b. There are two nasal sacs with separate apertures. Mandibles and limb arches are developed. (*Amphirhina*. Hck.).

a. The nasal passages do not communicate with the cavity of the mouth. There are no lungs, and the heart has but one auricle.

a. The skull is devoid of membrane bones.

III.—*Elasmobranchii*.

β. Membrane bones are developed in relation with the skull.

1. The optic nerves form a chiasma, and there are several rows of valves in the aortic bulb.

IV. *Ganoidei*.

2. The optic nerves simply cross, and there is only one row of valves in the aortic bulb.

V.—*Teleostei*.

b. The nasal passages communicate with the oral cavity. There are lungs, and the heart has two auricles.

VI.—*Dipnoi*.

I. The PHARYNGOBRANCHII.—This order contains but one species of fish, the remarkable Lancelet, or *Amphioxus lanceolatus*, which lives in sand, at moderate depths in the sea, in many parts of the world. It is a small semitransparent creature, pointed at both ends, as its name implies, and possessing no limbs, nor any hard epidermic or dermal covering.

The dorsal and caudal regions of the body present a low median fold of integument, which is the sole representative of the system of the median fins of other fishes. The mouth (Fig. 28, A, a) is a proportionally large oval aperture, which lies behind, as well as below, the anterior termination of the body, and has its long axis directed longitudinally. Its margins are produced into delicate ciliated tentacles, supported by semi-cartilaginous filaments, which

are attached to a hoop of the same texture placed around the margins of the mouth (Fig. 29, *f, g*). These probably represent the labial cartilages of other fishes. The oral aperture leads into a large and dilated pharynx, the walls of which are perforated by numerous clefts, and richly ciliated, so that it resembles the pharynx of an Ascidian (Fig. 28, B, *f, g*). This great pharynx is connected with simple gastric cavity which passes into a straight intestine, ending in the anal aperture, which is situated at the root of the tail at a little to the left of the median line (Fig. 28, A, *c*). The mucous membrane of the intestine is ciliated.

Fig. 28.

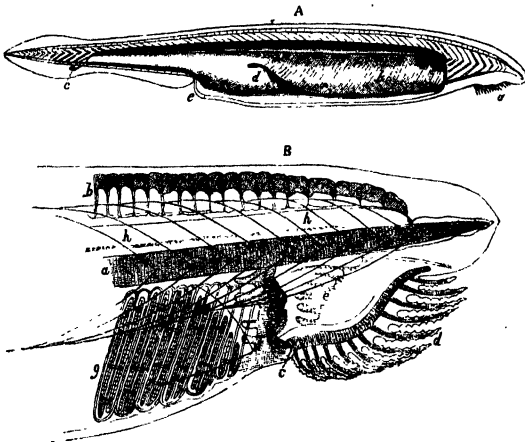


Fig. 28.—*Amphioxus lanceolatus*.—*a*, mouth; *b*, pharyngobranchial chamber; *c*, anus; *d*, liver; *e*, abdominal pore.—B, the head enlarged: *a*, the notochord; *b*, the representatives of neural spines, or fin-rays; *c*, the jointed oral ring; *d*, the filamentary appendages of the mouth; *e*, the ciliated lobes of the pharynx; *f, g*, part of the branchial sac; *h*, the spinal cord.

tine, ending in the anal aperture, which is situated at the root of the tail at a little to the left of the median line (Fig. 28, A, *c*). The mucous membrane of the intestine is ciliated.

An aperture called the abdominal pore (Fig. 28, A, *e*), placed in front of the anus, leads into a relatively spacious

cavity, which is continued forwards, on each side of the pharynx, to near the oral aperture. The water which is constantly propelled into the pharynx by its cilia, and those of the tentacles, is driven out through the branchial clefts, and makes its exit by the abdominal pore.

The liver (Fig. 28, A, *d*) is a saccular diverticulum of the intestine, the apex of which is turned forwards.

Fig. 29.

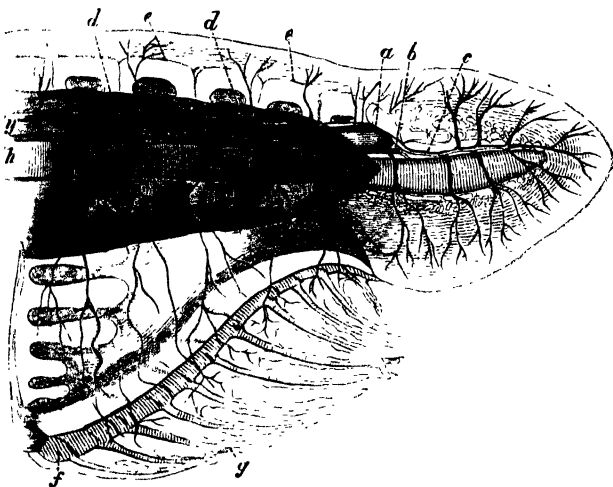


Fig. 29. - Anterior end of the body of *Amphioxus*:— *Ch*, notochord; *My*, myelon, or spinal chord; *a*, position of olfactory (?) sac; *b*, optic nerve; *c*, fifth (?) pair; *d*, spinal nerves; *e*, representatives of neural spines, or fin-rays; *f*, *g*, oral skeleton. The lighter and darker shading represents the muscular segments and their interspaces.

The existence of distinct kidneys is doubtful; and the reproductive organs are simply quadrate glandular masses, attached in a row, on each side of the walls of the visceral cavity, into which, when ripe, they pour their contents.

The heart retains the tubular condition which it possesses

in the earliest embryonic stage only, in other *Vertebrata*. The blood brought back from the body and from the alimentary canal enters a pulsatile cardiac trunk, which runs along the middle of the base of the pharynx, and sends branches up on each side. The two most anterior of these pass directly to the dorsal aorta; the others enter into the ciliated bars which separate the branchial slits, and, therefore, are so many branchial arteries. Contractile dilata-tions are placed at the bases of these branchial arteries. On the dorsal side of the pharynx the blood is poured, by the two anterior trunks, and by the branchial veins which carry away the aerated blood from the branchial bars, into a great longitudinal trunk, or dorsal aorta, by which it is distributed throughout the body.

Notwithstanding the extremely rudimentary condition of the liver, it is interesting to observe that a contractile trunk, which brings back the blood of the intestine, is distributed on the hepatic sac after the manner of a portal vein. The blood is collected again into another contractile trunk, which represents the hepatic vein, and is continued into the cardiac trunk at the base of the branchial sac. The corpuscles of the blood are all colourless and nucleated.

The skeleton is in an extremely rudimentary condition, the spinal column being represented by a notochord, which extends throughout the whole length of the body, and terminates, at each extremity, in a point (Fig. 28). The investment of the notochord is wholly membranous, as are the boundary-walls of the neural and visceral chambers, so that there is no appearance of vertebral centra, arches, or ribs. A longitudinal series of small semi-cartilaginous rodlike bodies, which lie above the neural canal, represent either neural spines or fin-rays (Fig. 28, B, b). Neither is there a trace of any distinct skull, jaws, or hyoidean apparatus; and, indeed, the neural chamber which occupies the place of the skull, has a somewhat smaller capacity than a segment of the spinal canal of equal length.

There are no auditory organs, and it is doubtful if a ciliated sac, which exists in the middle line, at the front

part of the cephalic region (Fig. 29, a), ought to be considered as an olfactory organ.

The myelon traverses the whole length of the spinal canal, and ends anteriorly without enlarging into a brain. From its rounded termination nerves are given off to the oral region, and to the rudimentary eye or eyes (Fig. 29, b, c).

According to M. Kowalewsky,* who has recently studied the development of *Amphioxus*, the vitellus undergoes complete segmentation, and is converted into a hollow sphere, the walls of which are formed of a single layer of nucleated cells. The wall of the one moiety of the sphere is next pushed in, as it were, until it comes into contact with the other, thus reducing the primitive cavity to nothing, but giving rise to a secondary cavity, surrounded by a double membrane. The operation is, in substance, just the same as that by which a double nightcap is made fit to receive the head. The blastoderm now acquires cilia, and becomes nearly spherical again, the opening into the secondary cavity being reduced to a small aperture at one pole, which eventually becomes the anus. M. Kowalewsky points out the resemblance, amounting almost to identity, of the embryo at this stage with that of many *Invertebrata*.

One face of the spheroidal blastoderm becomes flattened, and gives rise to *laminae dorsales*, which unite in the characteristically vertebrate fashion; and the notochord appears between and below them, and very early extends forwards, beyond the termination of the neural canal. The neural canal remains in communication with the exterior, for a long time, by a minute pore at its anterior extremity. The mouth arises as a circular aperture, developed upon the right side of the anterior end of the body, by the coalescence of the two layers of the blastoderm, and the subsequent perforation of the disc formed by this coalescence. The branchial apertures arise by a similar process, which takes place behind the mouth; and they are, at first, completely

* 'Mémoires de l'Académie Impériale des Sciences de St. Petersburg,' 1867.

exposed on the surface of the body. But, before long, a longitudinal fold is developed upon each side, and grows over the branchial apertures. The two folds eventually coalesce on the ventral side, leaving only the abdominal pore open. One cannot but be struck with the resemblance of these folds to the processes of integument which grow over the branchiæ of the amphibian larva; and, in like manner, inclose a cavity, which communicates with the exterior only by a single pore.

In a great many of the characters which have been enumerated—as, for example, in the entire absence of a distinct skull and brain, of auditory organs, of kidneys, of a chambered heart; in the presence of a saccular liver, of ciliated branchiæ and alimentary canal; and in the extension of the notochord forwards to the anterior end of the body—*Amphioxus* differs from every other vertebrated animal. Hence Professor Haeckel has proposed to divide the *Vertebrata* into two primary groups—the *Leptocardia*, containing *Amphioxus*; and the *Pachycardia*, comprising all other *Vertebrata*. The great peculiarities in the development of *Amphioxus*, and the many analogies with invertebrate animals, particularly the Ascidians, which it presents, lend much support to this proposition.

No fossil form allied to *Amphioxus* is known.

II. The MARSIPOBRANCHII.—In this order of the class *Pisces* the integument is devoid of scales or bony plates.

The spinal column consists of a thick persistent notochord enveloped in a sheath, but devoid of vertebral centra. The neural arches and the ribs may be represented by cartilages, and there is a distinct skull presenting cartilage at least in its base, and retaining many of the characters of the foetal cranium of the higher *Vertebrata*. The notochord terminates in a point in the base of this cartilaginous skull behind the pituitary body; and the skull is not moveable upon the spinal column. There are no jaws; but the palatopterygoid, the quadrate, the hyomandibular, and the hyoid apparatus of higher *Vertebrata*, are imperfectly repre-

sented (Fig. 30, *f, g, h*). In some genera a basket-like cartilaginous apparatus strengthens the walls of the oral cavity; while, in others, such a framework supports the gill-sacs.

The *Marsipobranchii* possess neither the pectoral nor the

Fig. 30.

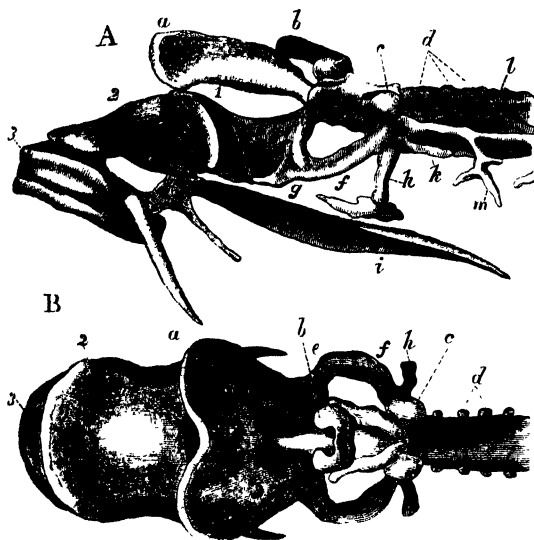


Fig. 30.—A, the skull of a Lamprey, viewed from the side; B, from above:—*a*, the ethmovomerine plate; *b*, the olfactory capsule; *c*, the auditory capsule; *d*, the neural arches of the spinal column; *e*, the palato-ptyergoid portion, *f*, probably, the metapterygoid, or superior quadrate, portion, and *g*, the inferior quadrate portion, of the subocular arch; *h*, stylohyal process; *i*, lingual cartilage; *k*, inferior, *l*, lateral, prolongation of the cranial cartilage; 1, 2, 3, accessory labial cartilages; *m*, branchial skeleton. The spaces on either side of 1 are closed by membrane.

pelvic pair of limbs, nor their arches. Horny teeth may be developed upon the roof of the palate, or upon the tongue, or may be supported by peculiarly developed labial carti-

lages. The alimentary canal is simple and straight, and the liver is not sac-like, but resembles that organ in other *Vertebrata*.

The heart has the usual piscine structure, consisting of a single auricle preceded by a venous sinus, a single ventricle, and an aortic bulb, all separated from one another by valves. This heart is contained in a pericardium, the cavity of which communicates with that of the peritoneum.

In *Myxine* the portal vein is rhythmically contractile.

The cardiac aorta, which is continued from the bulb, distributes its branches to the respiratory organs. These consist of antero-posteriorly flattened sacs, which communicate, directly or indirectly, on the inner side, with the pharynx, and, externally, with the surrounding medium.

In the Lamprey there are seven sacs, upon each side, which open externally by as many distinct apertures. Internally, they communicate with a long canal, which lies beneath the cesophagus and is closed behind, while anteriorly it communicates freely with the cavity of the mouth (Fig. 32, *Pr*).

The kidneys are well developed, and have the ordinary vertebrate structure, while the ureters open behind the rectum.

The brain, though very small, is quite distinct from the myelon, and presents all the great divisions found in the higher *Vertebrata*—that is to say, a fore-brain, mid-brain, and hind-brain. The fore-brain is further divided into rhinencephala, solid prosencephalic lobes, and a thalamencephalon; the hind-brain, into metencephalon and myelencephalon (Fig. 31).

The auditory organ is simpler than in other fishes, possessing only two semicircular canals and a sacculated vestibule in the Lamprey. In *Myxine* the whole organ is represented by a single circular membranous tube, without further distinction into canals and vestibule.

The *Marsipobranchii* differ remarkably, not only from the fishes which lie above them, but from all other vertebrate animals, in the characters of the olfactory organ, which consists of a sac placed in the middle line of the head, and

Fig. 31.

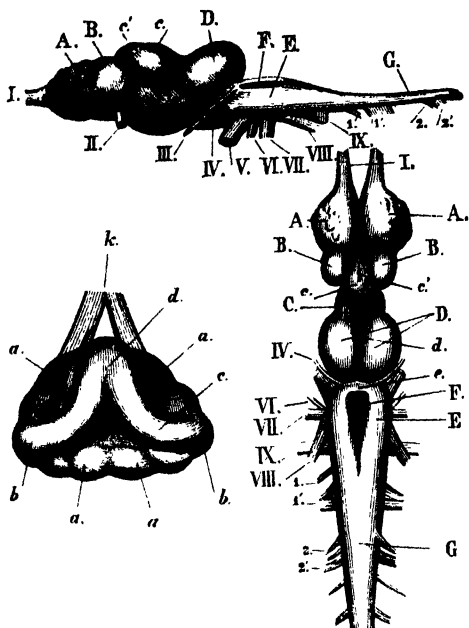


Fig. 31.—Side and upper views of the brain of *Petromyzon fluviatilis*, and an upper and inner view of the membranous labyrinth of *P. marinus*. The following letters refer to the figures of the brain:—I. the olfactory nerves, narrow anterior prolongations of the rhinencephalon (A); B, the prosencephalon; C, the thalamencephalon; D, the mesencephalon; E, the medulla oblongata; F, the fourth ventricle; G, the narrow band which is all that represents the cerebellum; H, the spinal cord; I. the optic; II. the oculomotorius; III. the patheticus; IV. the trigeminal; V. the abducens; VI. the facial, and the auditory; VII. the glossopharyngeal and pneumogastric; IX. the hypoglossal nerves; 1, 1', 2, 2', sensory and motor roots of the first two spinal nerves. In the figure of the membranous labyrinth: k, the auditory nerve; a, the vestibule; c, the two semicircular canals, which correspond with the anterior and posterior vertical canals of other *Vertebrata*; d, their union and common opening into the vestibule; b, the ampullæ.

having a single, median, external aperture. In all other *Vertebrata* there are two nasal sacs. In the Lampreys, the nasal sac terminates blindly below and behind, but in the Hags (*Myxine*), it opens into the pharynx. In no other fishes, except *Lepidosiren*, does the olfactory apparatus communicate with the cavity of the mouth.

The reproductive organs of the *Marsipobranchii* are solid plates suspended beneath the spinal column, and they have no ducts, but shed their contents into the abdomen, whence

Fig. 32.

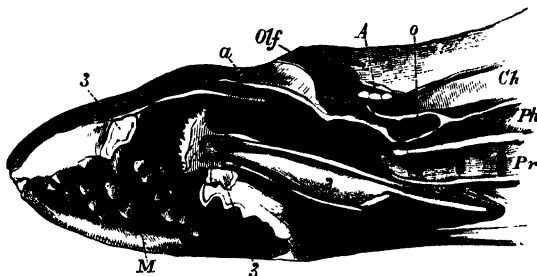


Fig. 32.--Vertical and longitudinal section of the anterior part of the body of a Lamprey (*Petromyzon marinus*):--*A*, the cranium with its contained brain; *a*, section of the edge of the cartilage marked *a*, in Fig. 30; *Olf*, entrance into the olfactory chamber, which is prolonged into the caecal pouch, *o*; *Ph*, the pharynx; *Pr*, the branchial channel, with the inner apertures of the branchial sacs; *M*, the cavity of the mouth, with its horny teeth; *2*, the cartilage which supports the tongue; *3*, the oral ring.

they pass out by an abdominal pore. In the early stages of their development the Lampreys present some singular resemblances to the *Amphibia*. They also undergo a metamorphosis, the young *Petromyzon* being so unlike the parent, that it was, until lately, regarded as a distinct genus—*Ammocetes*. But the young Lampreys never possess external branchial filaments or spiracula.

The *Marsipobranchii* are inhabitants of both fresh and salt water. The Myxinoids are remarkable for their parasitic habits—the Hag boring its way into the bodies of other

fishes, such as the Cod. No fossil *Marsipobranchii* are known. This circumstance may, in part, be due to the perishableness of their bodies; though horny teeth, like those of the Lampreys, might have been preserved under favourable circumstances.

III. The ELASMOBRANCHII.—This order contains the Sharks, the Rays, and the *Chimæra*.

The integument may be naked, and it never possesses scales like those of ordinary fishes; but, very commonly, it is developed into papillæ, which become calcified, and give rise to toothlike structures: these, when they are very small and close-set, constitute what is called *shagreen*. When larger and more scattered, they form dermal plates or tubercles; and when, as in many cases, they take the form of spines, these are called *dermal defences*, and, in a fossil state, *ichthyodorulites*. All these constitute what has been called a "*placoid exoskeleton*;" and, in minute structure, they precisely resemble teeth, as has been already explained. The protruded surfaces of the dermal defences are frequently ornamented with an elegant sculpturing, which ceases upon that part of the defence which is imbedded in the skin. The dermal defences are usually implanted in front of the dorsal fins, but may be attached to the tail, or, in rare cases, lie in front of the paired fins.

The spinal column exhibits a great diversity of structure: from a persistent notochord exhibiting little advance upon that of the *Marsipobranchii*, or having mere osseous rings developed in its walls, to complete vertebrae, with deep conical anterior and posterior concavities in their centra, and having the primitive cartilage more or less completely replaced by concentric, or radiating, lamellæ of bone. In the Rays, indeed, the ossification goes so far as to convert the anterior part of the vertebral column into one continuous bony mass.

The neural arches are sometimes twice as numerous as the centra of the vertebrae, in which case the added arches are termed *intercrural* cartilages.

The terminal part of the notochord is never enclosed within a continuous bony sheath, or *urostyle*. The extremity of the vertebral column is generally bent up, and the median fin-rays which lie below it are, usually, much longer than those which lie above it, causing the lower lobe of the tail to be much larger than the upper. Elasmobranchs with tails of this conformation are truly *heterocercal*, while those in which the fin-rays of the tail are equally divided by the spinal column, or nearly so, are *diphycercal* (p. 16). The Monkfish (*Squatina*) and many other *Elasmobranchii* are more *diphycercal* than *heterocercal*.

The ribs are always small, and may be quite rudimentary.

The skull is composed of cartilage, in which superficial pavement-like deposits of osseous tissue may take place, but it is always devoid of membrane bone. When moveable upon the spinal column, it articulates therewith by two condyles.

In its general form and structure, the cartilaginous skull of an *Elasmobranch* corresponds with the skull of the vertebrate foetus in its cartilaginous state, and there are usually more or less extensive membranous fontanelles in its upper walls. The ethmoidal region sends horizontal plates over the nasal sacs, the apertures of which retain their embryonic situation upon the under-surface of the skull.

Neither premaxillæ nor maxillæ are present, the "jaws" of an *Elasmobranch* consisting, exclusively, of cartilaginous representatives of the primary palato-quadrato arch and of Meckel's cartilage.

The former of these, the so-called upper jaw, may either be represented, as in the *Chimæra* (Fig. 33), by the anterior portion (*B*, *D*) of a triangular cartilaginous lamella, which stretches out from the sides of the base of the skull, and is continuous with the representative of the hyomandibular suspensorium; or there may be, on each side, a cartilaginous bar moveably articulated in front with the fore part of the skull; and, posteriorly, furnishing a condyle, with which the ramus of the lower jaw, representing Meckel's cartilage, articulates.

In the latter case, which is that met with in the Sharks and Rays (Figs. 34 & 35), a single cartilaginous rod (*g*) is moveably articulated with the skull, in the region of the periotic capsule, upon each side; and, by its opposite extremity, is connected by ligamentous fibres both with the palato-quadrate (*h*), and with the mandibular or Meckelian cartilage (*Mn*). This cartilaginous *suspensorium* represents

Fig. 33.

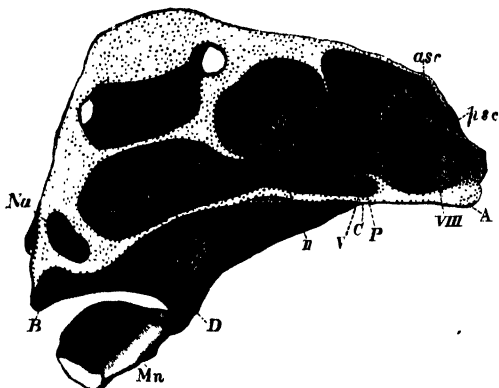


Fig. 33.—Vertical section of the skull of *Chimara monstrosa*, without the labial and nasal cartilages :—*A*, the basi-occipital region; *P*, the pituitary fossa; *Na*, partition between the olfactory sacs; *B*, alveolus for the anterior upper jaw tooth; *C*, *D*, the region of the triangular cartilage which answers to the hyomandibular and quadrate; *D*, *B*, that which answers to the quadrate, pterygoid, and palatine; *Mn*, the mandible; *I Or*, the interorbital septum; *asc* and *psc*, the anterior and posterior semicircular canals; *I*, *II*, *V*, *VIII*, exits of the olfactory, optic, fifth and eighth pairs of nerves.

the hyomandibular and the symplectic bones of the *Teleostei*, and gives attachment to the hyoidean apparatus (*Hy*). The latter consists of a lateral arch upon each side, united with its fellow, and with the branchial arches, by the intermeditation of medial basal elements below; and it is succeeded by a variable number of similar arches, which support the branchial apparatus.

From the hyoidean and from the branchial arches cartilaginous filaments pass directly outwards, and support the walls of the branchial sacs. Superficial cartilages, which lie parallel with the branchial arches, are sometimes superimposed upon these. There are no opercular bones, though cartilaginous filaments which take their place (Fig. 34, *Op*) may be connected with the hyomandibular cartilage; and, in the great majority of the *Elasmobranchii*, the apertures of the gill-sacs are completely exposed. But in one group, the *Chimæra*, a great fold of membrane extends back from the suspensorial apparatus, and hides the external gill-apertures.

Large accessory cartilages, called *labial*, are developed at the sides of the gape in many *Elasmobranchii*. (Figs. 34 & 35, *i*, *k*, *l*.)

The pectoral arch consists of a single cartilage on each side. The two become closely united together in the ventral median line, and are not directly connected with the skull. The pelvis is also represented by a pair of cartilages, which may coalesce, and are invariably abdominal in position.

There are always two pairs of lateral fins corresponding with the anterior and posterior limbs of the higher *Vertebrata*. The pectoral fins, the structure of which has already been described, are always the larger, and sometimes attain an enormous size relatively to the body.

In these fishes, teeth are developed only upon the mucous membrane which covers the palato-quadrate cartilage and the mandible. They are never implanted in sockets, and they vary greatly in form and in number.

In the Sharks they are always numerous, and their crowns are usually triangular and sharp, with or without serrations and lateral cusps. As a rule, the anterior teeth on each side have more acute, the posterior more obtuse crowns. In the Port Jackson shark (*Cestracion*), however, the anterior teeth are not more acute than the most obtuse teeth of the others, while the middle teeth acquire broad, nearly flat, ridged crowns, and the hindermost teeth are similar but smaller.

The Rays usually have somewhat obtusely-pointed teeth, but in *Myliobates*, the middle teeth have transversely elongated, and the lateral ones hexagonal, flat crowns, and the various teeth are fitted closely by their edges into a pavement. In *Aetobatis* only the middle transversely elongated teeth remain. In the Sharks and Rays the teeth are developed from papillæ, or ridges, situated at the bottom of a deep fold within the mucous membrane of the jaw. The teeth come to the edge of the jaw, and, as they are torn away or worn down by use, they are replaced by others, developed, in successive rows, from the bottom of the groove. No such successive development takes place in the *Chimæra*.

As in other fishes, there are no salivary glands. The wide œsophagus leads into a stomach which is usually spacious and sac-like, but sometimes, as in *Chimæra*, may be hardly distinct from the rest of the alimentary canal. No diverticulum filled with air, and constituting a swimming-bladder, as in Ganoid and many Teleostean fishes, is connected with either the œsophagus, or the stomach, though a rudiment of this structure has lately been discovered in some Elasmobranchs.

The intestine is short, and usually commences by a dilatation separated from the stomach by a pyloric valve. This duodenal segment of the intestine is usually known as the *Bursa Entiana*. It receives the hepatic and pancreatic ducts, and, in the fœtus, the vitelline duct. Beyond this part, the absorptive area of the mucous membrane of the small intestines is increased by the production of that membrane into a fold, the so-called *spiral valve*, the fixed edge of which usually runs spirally along the wall of the intestine. In some sharks (*Carcharias*, *Galeocerdo*) the fixed $\frac{3}{4}$ of the fold runs straight and parallel with the axis of intestine, and the fold is rolled up upon itself into a cylindrical spiral.

The short rectum terminates in the front part of a cloaca, which is common to it and the ducts of the renal and the reproductive organs. The peritoneal cavity communicates with that of the pericardium in front, and, behind, opens

externally by two *abdominal pores*. The heart presents a single auricle, receiving the venous blood of the body from a *sinus venosus*. There is a single ventricle, and the walls of the aortic bulb contain striped muscular fibres, and are rhythmically contractile, pulsating as regularly as those of the auricle and ventricle.

The interior of the bulb exhibits not merely a single row of valves at the ventriculo-bulbous aperture, but several other

Fig. 36.

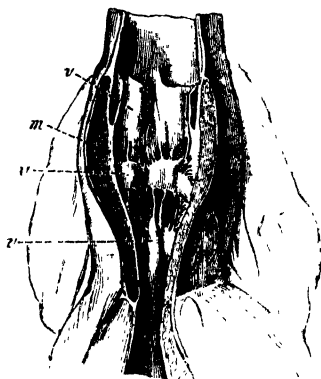


Fig. 36.--The aortic bulb of a Shark (*Lamna*), laid open to show the three rows of valves, v, r, r, and the thick muscular wall, m.

transverse rows of semilunar valves, which are attached to the walls of the bulb itself, and at its junction with the aorta. These valves must be of great importance in giving full effect to the propulsive force exerted by the muscular wall of the bulb.

In a good many *Elasmobranchii* there is a *spiracle*, or aperture leading into the cavity of the mouth, on the upper side of the head, in front of the suspensorium. From this aperture (which, according to the observations of Professor Wyman, is the remains of the first visceral cleft of the

embryo), as well as from the proper branchial clefts, long branchial filaments protrude, in the foetal state. These disappear in the adult, the respiratory organs of which are flattened pouches, with transversely-plaited walls, from five to seven in number. They open by external clefts upon the sides (Sharks and *Chimæra*), or under-surface (Rays), of the neck, and, by internal apertures, into the pharynx.

The anterior wall of the anterior sac is supported by the hyoidean arch. Between the posterior wall of the first, and the anterior wall of the second sac, and between the adjacent walls of the other sacs, a branchial arch with its radiating cartilages is interposed. Hence the hyoidean arch supports one series of branchial plates or laminae; while the succeeding branchial arches, except the last, bear two series, separated by a septum, consisting of the adjacent walls of two sacs with the interposed branchial skeleton.

The cardiac aorta, a trunk which is the continuation of the bulb of the aorta, distributes the blood to the vessels of these sacs; and it is there aerated by the water which is taken in at the mouth and forced through the pharyngeal apertures, outwards.

The kidneys of the *Elasmobranchii* do not extend so far forward as those of most other fishes. The ureters generally become dilated near their terminations, and open by a common urinary canal into the cloaca behind the rectum.

The brain is well developed. It usually presents a large cerebellum overlying the fourth ventricle, the side-walls of which (*corpora restiformia*) are singularly folded (Fig. 37. A., a); and moderate-sized optic lobes, which are quite distinct from the conspicuous thalamencephalon, or vesicle of the third ventricle. The third ventricle itself is a relatively wide and short cavity, which sends a prolongation forwards, on each side, into a large, single, transversely-elongated mass (Fig. 37, a), which is usually regarded as the result of the coalescence of the cerebral hemispheres, but is, perhaps,

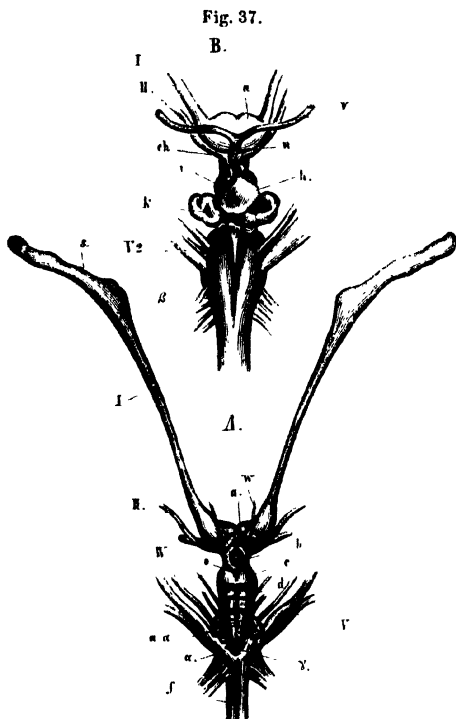


Fig. 37. — The brain of the Skate (*Raia batis*). *A.* From above; *B.* A portion of the ventral aspect enlarged: — *s*, the olfactory bulbs; *a*, the cerebral hemispheres which are united in the middle line; *b*, the thalamencephalon; *c*, the mesencephalon; *d*, the cerebellum; *aa*, the plaited bands formed by the corpora restiformia; *I*, *II*, *IV*, *V*, *V*., the cerebral nerves of the corresponding pairs; *f*, the medulla oblongata; *w*, a bloodvessel. In *B.*: *ch*, the chiasma of the optic nerves; *h*, the pituitary body; *n* and *r*, vessels connected with it; *k*, the *sacculus vasculosus*; *β*, the pyramids of the medulla oblongata.

more properly, to be considered as the thickened termination of the primitive encephalon, in which the *lamina terminalis* and the hemispheres are hardly differentiated. The large olfactory lobes are usually prolonged into pedicles, which dilate into great ganglionic masses where they come into contact with the olfactory sacs (Fig. 37, A., s). The latter always open upon the under-surface of the head. A cleft, which extends from each nasal aperture to the margin of the gape, is the remains of the embryonic separation between the naso-frontal process and the maxillo-palatine process, and represents the naso-palatine passage of the higher *Vertebrata*. The optic nerves fuse into a complete chiasma (Fig. 37, B., ch), as in the higher *Vertebrata*. In some Sharks, the eye is provided with a third eyelid or nictitating membrane, moved by a single muscle, or by two muscles, arranged in a manner somewhat similar to that observed in birds. In both Sharks and Rays, the posterior surface of the sclerotic presents an eminence which articulates with the extremity of a cartilaginous stem proceeding from the bottom of the orbit.

Except in *Chimæra*, the labyrinth is completely inclosed in cartilage. In the Rays the anterior and posterior "semicircular" canals are circular, and open by distinct narrow ducts into the vestibular sac. In the other *Elasmobranchii* they are arranged in the ordinary way. A passage leading from the vestibular sac to the top of the skull, and opening there by a valvular aperture, represents the canal by which, in the vertebrate embryo, the auditory involution of the integument is, at first, connected with the exterior.

The testes are oval, and are provided with an epididymis and vas deferens, as in the higher *Vertebrata*. The vas deferens of each side opens into the dilated part of the ureter. Attached to the ventral fins of the male are peculiar appendages, termed *claspers*.

The ovaria are rounded, solid organs. There are usually two, but in some cases, as in the Dogfishes and nictitating Sharks, the ovary is single and symmetrical. The oviducts

are true Fallopian tubes, which communicate freely with the abdominal cavity at their proximal ends. Distally, they dilate into uterine chambers, which unite and open into the cloaca.

The eggs are very large, and comparatively few.

The Dogfishes, the Rays, and the *Chimæra* are oviparous, and lay eggs enclosed in hard leathery cases; the others are viviparous, and in certain species of *Mustelus* (*lævis*) and *Carcharias*, a rudimentary placenta is formed, the vascular walls of the umbilical sac becoming plaited, and interdigitating with similar folds of the wall of the uterus.

The embryos of most Elasmobranchs are, at first, provided with long external branchial filaments, which proceed from the periphery of the spiracle, as well as from most of the branchial arches. These disappear, and are functionally replaced by internal gills as development advances.

The *Elasmobranchii* are divided into two groups, the *Holocephali* and the *Plagiostomi*.

In the *Holocephali* the palato-quadrate and suspensorial cartilages are united with one another and with the skull into a continuous cartilaginous plate; the branchial clefts are covered by an opercular membrane. The teeth are very few in number (not more than six, four of which are in the upper, and two in the lower jaw, in the living species) and differ in structure from those of the *Plagiostomi*. This suborder contains the living *Chimæra* and *Callorhynchus*, the extinct Mesozoic *Edaphodon* and *Passalodon*; and, very probably, some of the more ancient Elasmobranchs, the teeth of which are so abundant in the Carboniferous limestones.

In the *Plagiostomi*, the palato-quadrate and suspensorial cartilages are distinct from one another, and are moveable upon the skull. The branchial clefts are not covered by any opercular membrane. The teeth are usually numerous.

The *Plagiostomi* are again subdivided into the Sharks (*Selachii* or *Squali*), with the branchial apertures at the sides

of the body, the anterior ends of the pectoral fins not connected with the skull by cartilages, and the skull with a median facet for the first vertebra; and the Rays (*Rajæ*), with the branchial clefts on the under-surface of the body, the pectoral fins united by cartilages to the skull, and no median articular facet upon the occiput for the first vertebra.

The *Elasmobranchii* are essentially marine in their habits; though Sharks are said to occur very high up in some of the great rivers of South America.

Both divisions of the *Plagiostomi* occur in the Mesozoic rocks. In the Palæozoic epoch, dermal defences and teeth of *Elasmobranchii* abound in the Permian and Carboniferous formations, and are met with in the Upper Silurian rocks. But, except in the case of *Pleuracanthus* (a Selachian), it is impossible to be certain to what special divisions they belong.

IV. The GANOIDEI.—In former periods of the world's history this was one of the largest and most important of the orders of fishes; but, at present, it comprises only the seven genera—*Lepidosteus*, *Polypterus*, *Calamoichthys*, *Amia*, *Accipenser*, *Scapirhynchus*, and *Spatularia*, which are either partially, or wholly, confined to fresh water, and are found only in the northern hemisphere. These fishes differ very widely from one another in many points of their organization, but agree in the following characters, some of which they possess in common with the *Elasmobranchii*, and others with the *Teleostei*. Thus:—

a. The *bulbus aortæ* is rhythmically contractile, and provided with several rows of valves, as in the *Elasmobranchii*.

b. The optic nerves unite in a chiasma, as in the *Elasmobranchii*.

c. There is a well-developed spiral valve in the intestine, as in the *Elasmobranchii*, in all but *Lepidosteus*, which possesses only a rudiment of such a valve.

On the other hand—

a. The branchial processes are not fixed throughout their extent to the wall of a branchial sac, which extends beyond

them, as in the *Elasmobranchii*; but their extremities project freely beyond the edge of the septum which separates each pair of branchial clefts, as in the *Teleostei*; and, as in the *Teleostei*, they are covered by a bony operculum.

b. There is a large air-bladder connected by a permanently open *pneumatic duct* with the œsophagus, as in many *Teleostei*.

c. As in the *Teleostei*, there is no cloaca.

The ventral fins are always abdominal in position. The tail is diphycercal, or heterocercal, and the terminal portion of the notochord is not ossified. The cavity of the abdomen

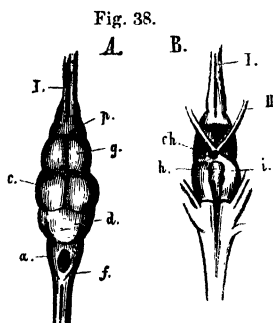


Fig. 38.—The brain of *Lepidosteus semiradiatus*. A. From above; B. From below:—f, the medulla oblongata; d, the cerebellum; c, the optic lobes of the mesencephalon; g, the cerebral hemispheres; h, the pituitary body; i, the lobi inferiores. Ch, the chiasma; I., olfactory; II., optic nerves.

is placed in communication with the exterior by abdominal pores. Finally, the ducts of the reproductive organs communicate with those of the permanent urinary apparatus, which is, in part, an Elasmobranch, in part, an Amphibian, character.

The exoskeleton presents the most extreme variations in the *Ganoidei*. *Spatularia* is naked; *Accipenser* and *Scaphirhynchus* develop numerous dermal plates composed of true bone; *Amia* is covered with overlapping cycloid scales; *Lepidosteus* and *Polypterus* have solid, rhomboidal, enamelled

scales, which not only overlap, but are fitted together by pegs and sockets, where their anterior and posterior edges come into contact.

The endoskeleton is not less diversely modified; and it is worthy of remark that no sort of relation, either direct or inverse, is traceable between the completeness of the endoskeleton and that of the exoskeleton. Thus *Spatularia*, *Scapirhynchus*, and *Accipenser* have a persistent notochord, in the sheath of which mere cartilaginous rudiments of the arches of vertebræ appear. The ribs, when present, are partially ossified. *Polypterus* and *Amia* have fully ossified vertebræ, the centra of which are amphicœlous. *Lepidosteus* also has fully ossified vertebræ; but their centra are opisthocœlous, having a convexity in front and a concavity behind, as in some *Amphibia*.

More or fewer of the anterior vertebræ, or their cartilaginous representatives, are united with one another, and with the posterior part of the skull. And the cranium may consist principally of cartilage, membrane bones being superadded; or the primordial cartilage may be largely superseded by bone, as in the *Teleostei*.

Spatularia, *Scapirhynchus*, and *Accipenser* have skulls of the former description. The cranium is one mass of cartilage, continuous behind with the coalesced anterior spinal cartilages, so as to be immoveably connected with the spinal column. The notochord enters its base, and terminates in a point behind the pituitary fossa. In front, the cartilage is produced into a beak, which, in *Spatularia*, is very long, flattened, and spatulate. In the perichondium of the base of the skull, median bones, answering to the vomer and to the parasphenoid of Teleostean fishes, are developed; and, in that of its roof, ossifications, which represent the parietals, frontals, and other membrane bones of the *Teleostei*, appear.

The framework of the jaws in *Spatularia* is very similar to that in the *Elasmobranchii*. There is a partly cartilaginous, and partly ossified, suspensorial cartilage (*A*, *B*, Fig. 39), which gives attachment below, directly, to the

hyoidean arch (*Hy*) and, indirectly, to the jaws. The latter consist of a palato-quadrate cartilage (*D*) united by ligament with its fellow, and with the prefrontal region of the skull at *F*.; and presenting, at its posterior end, a convex articular head to the cartilage of the mandible, or Meckelian cartilage, *Mn*. It is obvious that *A*, *B* corresponds with the hyomandibular, or suspensorial, cartilage in the Sharks and Rays; *D*, with the palato-quadrate carti-

Fig. 39.

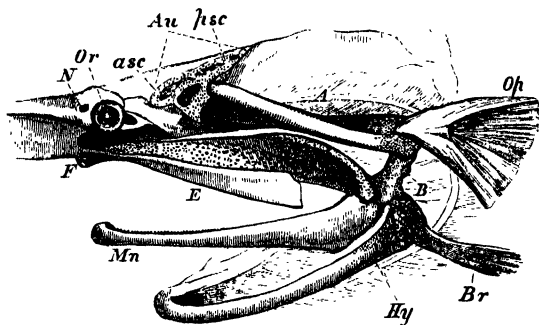


Fig. 39.—Side-view of the skull of *Spatularia*, with the beak cut away, and the anterior (*asc*), and posterior (*psc*), semicircular canals exposed:—*Au*, auditory chamber; *Or*, the orbit with the eye; *N*, the nasal sac; *Hy*, the hyoidean apparatus; *Br*, the representatives of the branchiostegal rays; *Op*, operculum; *Mn*, mandible; *A*, *B*, suspensorium; *D*, palato-quadrate cartilage; *E*, maxilla.

lage, or so-called "upper jaw," and the cartilage of the mandible with the lower jaw in these animals. But, in the Ganoid fish, an osseous operculum (*Op*) is attached to the hyomandibular; and a branchiostegal ray (*Br*) to the more strictly hyoidean part of the skeleton of the second visceral arch; while a membrane bone (*E*) representing the maxilla, and another (*Mn*) the dentary, of the lower jaw in *Teleostei*, are developed in connection with the palato-quadrate and mandibular cartilages.

In the Sturgeon (Fig. 40), the membrane bones of the roof of the skull are more numerous and distinct than in *Spatularia*, and large dermal bones (*I, K, L*) are united with them, to form the great cephalic shield. The suspen-

Fig. 40.

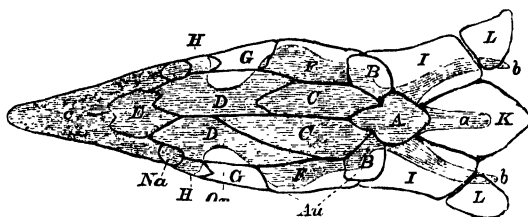


Fig. 40.—The cartilaginous skull of a Sturgeon, with the cranial bones. The former is shaded, and supposed to be seen through the latter, which are left unshaded:—*a*, ridge formed by the spinous processes of the anterior vertebræ; *b, b*, lateral winglike processes; *c*, rostrum; *Au*, position of the auditory organ; *Na*, position of the nasal sacs; *Or*, that of orbit. The membrane bones of the upper surface are: *A*, the analogue of the supra-occipital; *B, B*, of the epiotics; *E*, of the ethmoid; *G, G*, of the postfrontals; *H, H*, of the prefrontals; *C, C*, the parietals; *D, D* are the frontals, and *F, F* the squamosals; *K*, the anterior dermal scute; *I, I* and *L, L*, dermal ossifications connecting the pectoral arch with the skull.

Fig. 41.

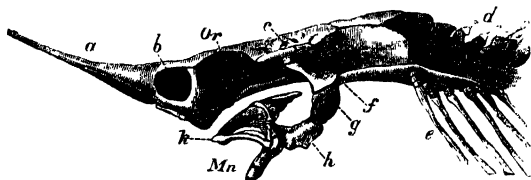


Fig. 41.—Side-view of the cartilaginous cranium of *Accipenser*:—*a*, rostrum; *b*, nasal chamber; *Or*, orbit; *c*, auditory region; *d*, coalesced anterior vertebræ; *e*, ribs; *f, g, h*, suspensorium; *k*, palato-maxillary apparatus; *Mn*, mandible.

sorium (*f, g, h*, Fig. 41) is divided into two portions, to the lower of which (at *h*) the proper hyoid is attached; and the palato-quadrates, with their subsidiary ossifications,

are so loosely connected with the floor of the skull, that the jaws can be protruded and retracted to a considerable extent.

In *Lepidosteus*, *Polypterus*, and *Amia*, the skull presents not only membrane bones, but, in addition, basi-occipital, ex-occipital, and pro-otic ossifications of the primordial cartilage, to which others may be added. The vomers are double, as in the *Amphibia* (? *Polypterus*). The apparatus of the jaws has become modified in accordance with the Teleostean type of structure. The suspensorium consists of two ossifications united by a cartilaginous intermediate portion. The upper—broad, and moveably articulated with the periotic capsule—is the *hyomandibular*; the lower answers to the *symplectic* of osseous fishes. The cartilaginous palatoquadrate arcade is, in part, replaced by a series of bones: the palatine lies in front, and is connected with the prefrontal region of the skull; behind it, lie representatives of the pterygoid, the metapterygoid, the ectopterygoid; and, most posteriorly, of the quadrate bone. The last furnishes a condyle to the articular element of the mandible. The symplectic is either loosely connected with the quadrate, as in *Lepidosteus*, or more closely united with it, as in the other genera.

In *Lepidosteus* and *Amia*, a strong and long membrane bone, the *preoperculum*, is developed on the outer side of the hyomandibular and quadrate bones, and connects them still more firmly together.

The maxilla is represented by a series of small separate ossifications in *Lepidosteus*. The proximal end of the mandibular cartilage ossifies, and becomes a distinct *articular*. A *dentary* element is added on the outer, and a *splénial* one upon the inner side of the cartilage; and in *Lepidosteus*, *angular*, *supra-angular*, and *coronary* elements are added, so that the components of the mandible are as numerous as in reptiles. *Lepidosteus* and *Amia* have branchiostegal rays, but *Polypterus* has none—at any rate, of the ordinary kind. A single *jugular* plate is developed between the rami of the mandible in *Amia*, and there are two such

plates in *Polypterus*, which may possibly represent branchiostegal rays.

In *Accipenser*, *Spatularia*, and *Amia*, the pectoral arch presents two constituents: one, internal and cartilaginous, answers to the cartilaginous pectoral arch of the *Elasmobranchii*, and to the scapula and coracoid of the higher *Vertebrata*; the other, external, consists of membrane bones representing the clavicular, supra-clavicular, and post-clavicular bones of the *Teleostei*. In *Lepidosteus* one centre of ossification appears in the cartilage; in *Polypterus*, two. The upper represents the scapula, and the lower the coracoid.

It has been already stated (p. 39) that *Polypterus* comes nearest to the *Elasmobranchii* in the structure of the rest of the limb. The numerous dermal fin-rays, all nearly equal in size, are connected with the rounded periphery of the broad and elongated disc formed by the skeleton of the fin; and the scaly integument is continued to the bases of the fin-rays, which thus seem to fringe a lobe of the integument. Hence the fin is said to be *lobate*. In the other genera, only two of the basal cartilages are present, and some of the *radialia* come into contact with the shoulder-girdle between them. In addition, the anterior dermal fin-ray is much larger than the others, and becomes directly connected with the anterior basal cartilage. Thus, in the structure of their fins, as in so many other characters, the *Ganoidei* are intermediate between the *Elasmobranchii* and the *Teleostei*.

In certain Ganoids, as *Lepidosteus*, *Accipenser*, and many fossil genera, the anterior margins of the anterior fin-rays of the dorsal fins, bear a single or a double series of small scales, or spines, called *fulera*.

In *Accipenser* and *Polypterus*, *spiracula*, or openings which communicate with the mouth, lie on the top of the head, in front of the suspensorium, as in many *Elasmobranchs*.

Lepidosteus, *Accipenser*, and *Scapirhynchus*, have branchiæ attached to the hyoidean arch, as in the *Elasmobranchii*. They are now called *opercular gills*.

In *Polypterus* the air-bladder is double and sacculated.

and the pneumatic duct opens upon the ventral aspect of the œsophagus. The air-bladder thus becomes exceedingly like a lung; but its vessels are in communication with those of the adjacent parts of the body—not with the heart, as in a true lung.

In *Lepidosteus*, the ducts of the male and female reproductive organs are continuous with those bodies, and each duct opens into the dilated ureter of its side. In the other

Fig. 42.

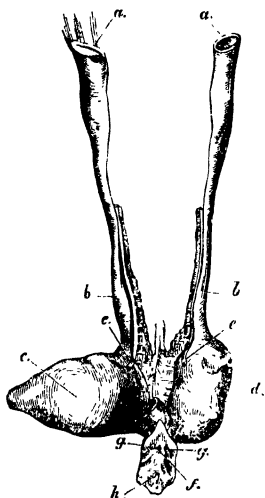


Fig. 42.—The female reproductive organs of *Amia calva*:—*a, a*, the open ends of the genital ducts; *b, b*, oviducts; *c, d*, the right and left divisions of the urinary bladder; *e, e*, the openings of the ureters into the bladder; *f*, the anus; *g, g*, the abdominal pores; *h*, the urogenital aperture.

Ganoids the proximal ends of the genital ducts, in both sexes, open widely into the abdominal cavity. In *Polypterus* the united ureters open into the cavity of the confluent oviducts, while, in the other Ganoids, the oviducts open into the dilated ureters. (Fig. 42.)

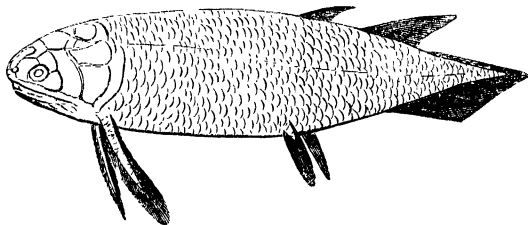
When the fossil, as well as the existing *Ganoidei*, are taken into account, they form a large order, divisible into the following suborders:—1. *Amiadae*, 2. *Lepidosteidae*, 3. *Crossopterygidae*, 4. *Chondrosteidae*, all of which have living representatives; while the other three—viz., 5. *Cephalaspidae*, 6. *Placodermi*, and 7. *Acanthodidae*—have been extinct since the Palæozoic epoch, and are only ranged among the Ganoids provisionally, inasmuch as we have no knowledge of their internal anatomy.

1. The *Amiadae* have a single living representative in the rivers of North America—*Amia calva*; and it is not certain that any member of the group occurs in the fossil state. The cycloid scales, preoperculum, single median jugular plate, branchiostegal rays, non-lobate paired fins, and heterocercal tail, diagnose the suborder.

2. The *Lepidosteidae* have rhomboidal enamelled scales, a preoperculum, branchiostegal rays, non-lobate paired fins, and heterocercal tail. These are represented in the rivers of North America at the present day, and in tertiary formations, by *Lepidosteus*; in the Mesozoic rocks, by a great variety of genera—*Lepidotus*, *Echmodus*, *Dapedius*, &c.; and, in the Palæozoic epoch, by *Paleoniscus* in the Carboniferous, and probably by *Cheirolepis*, in the Devonian, formation.

3. In the *Crossopterygidae* the scales vary in thickness and ornamentation, and may be thin and cycloid, or thick and

Fig. 43.—Restoration of *Holoptychius*.



rhomboid. The dorsal fins are either two in number, or, if single, very long, or multifold. The pectoral fins, and usually the ventrals, are lobate; they are sometimes rounded, as

in *Polypterus*—sometimes greatly elongated and almost filiform, as in *Holoptychius* (Fig. 43). There are no branchiostegal rays, but two principal, and sometimes many smaller lateral, jugular plates. The tail may be either diphyccercal or heterocercal.

The only living representatives of this suborder are *Polypterus* and *Calamoichthys*, which inhabit the rivers of North Africa. Neither of these are known to occur in the fossil state. The only family of the suborder at present known among Mesozoic fossils is that of the *Cœlacanthini*, a remarkable group of fishes with a persistent notochord, rudimentary ribs, an air-bladder with ossified walls, and a single interspinous bone for each of the two dorsal fins. The *Cœlacanthini* also occur in the Carboniferous formation; and the great majority of the *Crossopterygidae* are found in this and the Devonian formations (*Osteolepis*, *Diplopterus*, *Glyptolæmus*, *Megalichthys*, *Holoptychius*, *Rhizodus*, *Dipterus*, *Phaneropleuron*, &c.). *Megalichthys*, *Diplopterus*, and probably a few other of these fishes, have partially ossified vertebral centra; the rest possessed a persistent notochord. It is by the *Crossopterygidae* that the Ganoids are especially connected with the *Dipnoi*, and, through them, with the *Amphibia*.

4. The *Chondrosteidae* are either naked, or have dermal plates of bone in the place of scales. Neither the pectoral nor the ventral fins are lobate. The branchiostegal rays are few or absent, the tail is heterocercal. There are no cartilage bones in the brain-case. The teeth are very small, or absent.

The Sturgeons (*Accipenser*)—which inhabit the northern rivers of Europe, Asia, and America, occasionally migrating to the sea—*Spatularia*, and *Scapirhynchus* (found in the rivers of North America), are the recent members of this group, which is represented, in the older Mesozoic rocks, by *Chondrosteus*.

5. The *Cephalaspidae* are remarkable fishes, probably allied to the *Chondrosteidae*, which occur only in the Lower Devonian and the Upper Silurian rocks, and are some of

the oldest fish at present known. The head is covered by a continuous shield, which has the structure of true bone, in *Cephalaspis*, but more resembles certain piscine scales, in *Pterapsis*. The shield is prolonged into two horns at its posterolateral angles, and a median dorsal backward prolongation usually bears a spine, in *Cephalaspis*; the body is covered with flat bony scales or plates, and possesses two large pectoral fins. The characters of the body and fins of *Pterapsis* are unknown. Notwithstanding the excellent preservation of many of the specimens of these fishes, they have, as yet, yielded no evidence of jaws or teeth. Should jaws be absent, the *Cephalaspidæ* would approach the *Marsipobranchii* more nearly than any of the other amphirhine fishes do.

6. The *Placodermi*, comprising the genera *Coccosteus*, *Pterichthys*, *Asterolepis*, and some others, are known to occur only in the Devonian and Carboniferous formations. In these fishes the pectoral region of the body is incased in great bony plates, which, like those of the skull, are ornamented with dots of enamel. The caudal region was covered with small scales in *Pterichthys*, while in *Coccosteus* it appears to have been naked. The pectoral member of *Pterichthys* is exceedingly long, covered with suturally-united bony plates, and united with the thoracic plates by a regular joint. In *Coccosteus* the pectoral member seems to have had the ordinary construction. The bones of the head and thorax of *Coccosteus* nearly resemble those of certain Siluroid fishes (e.g. *Clarias*) in their form and arrangement, and it seems probable that the *Placodermi* were annectent forms between the physostome *Teleostei* and the *Ganoidei*.

7. The *Acanthodidæ*, on the other hand, seem to have connected the *Ganoidei* with the *Elasmobranchii*. The scales of these fishes of the Devonian and Carboniferous formations are very small, and similar to shagreen; spines, resembling the dermal defences of the *Elasmobranchii*, are placed in front of more, or fewer, of the median and of the paired fins. The skull appears to have been unossified, and the pectoral arch seems to have consisted of a single bony hoop.

The *Pycnodontidæ*, which are commonly grouped among the Ganoids, are fishes with much-compressed bodies, like the John Dory or the Filefishes, covered with large rhomboidal enamelled scales, from which bony ridges projected internally, and were imbedded in the integument. The notochord is persistent, but the neural arches and the ribs are ossified. The proximal ends of the ribs, imbedded in the sheath of the notochord, are but little expanded in the more ancient members of the group, while, in the more modern species, they enlarge, and at length unite by serrated sutures, giving rise to spurious vertebræ. The skull is high and narrow, as in *Balistes*; the premaxillæ are small, and there are no teeth in the maxillæ, but several longitudinal series of crushing teeth (the vomer and parasphenoid?) are attached to the base of the skull. These bite between the rami of the mandible, which are also armed with several rows of similar teeth. The teeth of the Pycnodonts have no vertical successors. The pectoral fins are small, the ventral, obsolete. The Pycnodonts are all extinct, but existed, formerly, for a very long period of time—their fossil remains occurring in rocks from the Carboniferous to the older Tertiary formations, inclusively. They present curious features of resemblance to the plectognath *Teleostei*.

The remains of Ganoid fishes began to appear in the Upper Silurian rocks at the same time as those of the *Elasmobranchii*, with which they constitute the oldest Vertebrate Fauna; they abound in the Devonian formation, and constitute, with the *Elasmobranchii*, the whole of the Palæozoic Fish Fauna. We are in ignorance of the true affinities of *Tharsis* and *Thrissops*, and of the *Hoplopleuridæ*; but unless some, or all, of these are Teleosteans, Ganoids and Elasmobranchs, alone, constitute the Fish Fauna of the Mesozoic formations, as far as the bottom of the Cretaceous series.

V. The TELEOSTEI.—The osseous fishes are occasionally devoid of any exoskeleton. Sometimes they present scattered dermal plates of true bone; or, as in the Trunkfishes

(*Ostracion*), the body may be incased in a complete cuirass, which is calcified, but has not the structure of bone. Again, as in the Filefishes (*Balistes*), the skin may be beset with innumerable small spines, somewhat like those which form the shagreen of the Elasmobranchs in appearance, though they differ from them in structure. But, usually, the exoskeleton of the Teleosteans takes the form of overlapping scales, which rarely exhibit the lacunæ characteristic of true bone. The free portions of the scales are sometimes smooth, and rounded at the edge, when they are termed *cycloid*; or they are roughened with ridges and minute spines, when they are called *ctenoid*.

The spinal column always presents ossified vertebral centra, and the primordial cartilage of the skull is more or less replaced by bone. The centra of the vertebræ are usually biconcave, each face presenting a deep conical hollow. In certain Eels (*Symbranchus*), the centra of most of the vertebræ are flat in front and concave behind, the most anterior possessing a convexity in front. In many Siluroid fishes a certain number of the anterior vertebræ are ankylosed together, and with the skull, into one mass, as in the Ganoids.

The vertebræ are distinguishable only into those of the trunk and those of the tail. The latter are provided with complete inferior arches, traversed by the caudal artery and vein. The former usually possess ribs, but these do not unite with one another, nor with any sternum, in the ventral median line, and they enclose the thoracico-abdominal viscera. The vertebræ are commonly united by zygapophyses, or oblique processes, placed above the centra; in addition to which, the lower margins of the centra are, not unfrequently, united by additional articular processes. Transverse processes commonly exist, but the ribs are articulated with the bodies of the vertebræ, or with the bases of the transverse processes, not with their extremities.

When a dorsal fin exists in the trunk, its rays are articulated with, and supported by, elongated and pointed bones—the *interspinous bones*, which are developed around pre-

existing cartilages, and lie between, and are connected with, the spines of the vertebræ. The fin-rays may be entire and completely ossified, or they may be transversely jointed and longitudinally subdivided at their extremities. Not unfrequently, the articulation between the fin-rays and the interspinous bone is effected by the interlocking of two rings—one belonging to the base of the fin-ray and its included dermal cartilage, and the other to the summit of the interspinous bone—like the adjacent links of a chain.

In all Teleostean fishes the extremity of the spinal column bends up, and a far greater number of the caudal fin-rays lie below than above it. These fishes are, therefore, strictly speaking, heterocercal. Nevertheless, in the great majority of them (as has been already mentioned, p. 16), the tail seems, upon a superficial view, to be symmetrical, the spinal column appearing to terminate in the centre of a wedge-shaped hypural bone, to the free edges of which the caudal fin-rays are attached, so as to form an upper and a lower lobe, which are equal, or subequal. This characteristically Teleostean structure of the tail-fin has been termed homocercal—a name which may be retained, though it originated in a misconception of the relation of this structure to the heterocercal condition.

In no Teleostean fish is the bent-up termination of the notochord replaced by vertebræ. Sometimes, as in the Salmon (Fig. 6, p. 17), it becomes ensheathed in cartilage, and persists throughout life. But, more usually, its sheath becomes calcified, and the urostyle thus formed coalesces with the dorsal edge of the upper part of the wedge-shaped hypural bone, formed by the ankylosis of a series of ossicles, which are developed in connection with the ventral face of the sheath of the notochord.

In the caudal region of the body, interspinous bones are developed between the spines of the inferior arches of the vertebræ, and bear the fin-rays of the anal and, in part, of the caudal fin.

The *Teleostei* differ very much in the extent to which the primordial cranium persists throughout life. Sometimes,

as in the Pike (Figs. 44 & 45), it grows with the growth of the fish, and only becomes partially ossified; in other cases it almost disappears. A basi-occipital (*B.O.*), ex-occipital (*E.O.*), and supra-occipital (*S.O.*) bone are developed in it.

Fig. 44.

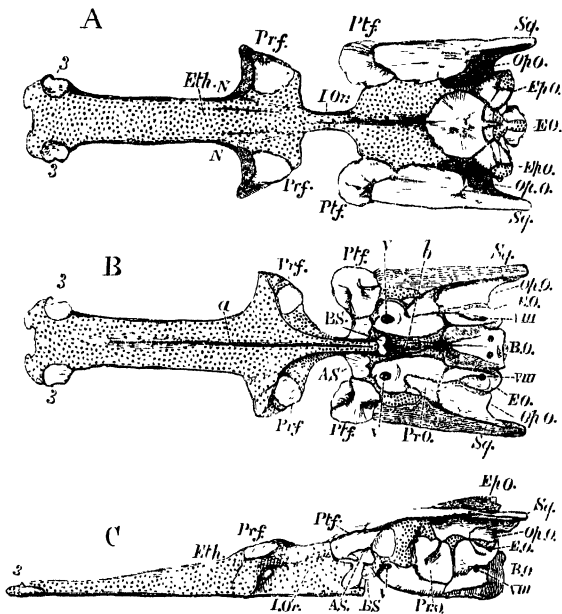


Fig 44.—The cartilaginous cranium of the Pike (*Esox lucius*), with its intrinsic ossifications; viewed, A, from above; B, from below; C, from the left side:—*N*, *N*, nasal fossæ; *I.Or.*, interorbital septum; *a*, groove for the median ridge of the parasphenoid; *b*, canal for the orbital muscles. *Sq.*, wrongly so marked, is the Pterotic. *V.* and *VIII.* mark the exits of the fifth and pneumogastric nerves; 3, 3, small ossifications of the rostrum.

and form a complete occipital segment. The proper basi-sphenoid (*BS*) bone is always a very small, and usually somewhat Y-shaped, bone. The alisphenoids (*AS*) some-

times are and sometimes are not developed. The pre-

Fig. 45.

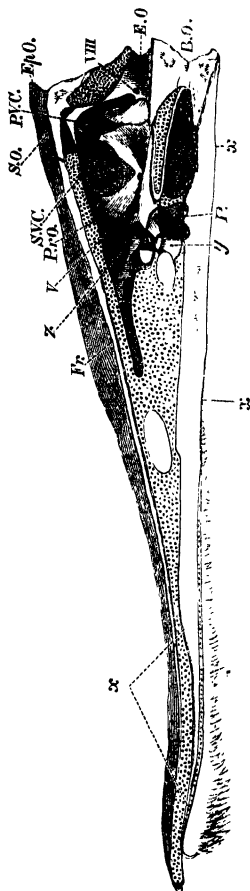


Fig. 45.—Longitudinal and vertical section of a fresh Pike's skull.—
The cut surface of cartilage is dotted. For S.V.C., and P.V.C.,

read *a.s.c.*, anterior, and *p.s.c.*, posterior semicircular canal; *x*, the parasphenoid; *y*, the basisphenoid; *Vo*, the vomer; *P.*, the pituitary fossa.

sphenoidal and orbitosphenoidal regions commonly, but not always, remain unossified.

In most osseous fishes, the base of the skull in front of the basisphenoid is greatly compressed from side to side, and forms an interorbital septum (*I. Or.*). The anterior moiety of the cranial cavity is consequently reduced to a comparatively narrow passage above the septum (Fig. 45). In the Siluroid and Cyprinoid fishes, however, this septum is not formed, and the cranial cavity is of nearly equal size throughout, or gradually diminishes forwards. The ethmoidal cartilage usually remains unossified, but sometimes, as in the Pike, ossification may take place in it. (Fig. 44, 3, 3.) The antorbital, or lateral ethmoidal, processes of the primordial cranium ossify, and give rise to the prefrontal bones (*Prf.*). The postorbital processes also ossify as postfrontals (*Ptf.*). The upper and posterior part of the primordial cranium exhibits five processes—one postero-median, two postero-lateral, and two postero-external. The postero-median ossifies as part of the supra-occipital (*S.O.*) The postero-lateral ossifies as part of the epiotic (*Ep.O.*), which lies upon the summit of the superior vertical semicircular canal. The postero-external closely corresponds with the squamosal of the higher *Vertebrata* in position; but, as a cartilage bone, it corresponds with an ossification of the capsule of the ear, called *pterotie* in the higher *Vertebrata*. Not unfrequently, as in the Cod, for example, the opisthotic (*Op.O.*) is a distinct bone, and enters into the formation of the postero-external process. The pro-otic (*Pr.O.*) is always a well-developed bone, and occupies its regular place, in front of the anterior vertical semicircular canal, and behind the exit of the trigeminal nerve.

In addition to these cartilage bones, the brain-case of osseous fishes is additionally defended by numerous membrane bones. These are, on the roof of the skull—

1. The parietal bones (*Pa.*), which sometimes meet in a

sagittal suture, as in most of the higher *Vertebrata*, but are very generally separated by the junction of the *frontals* with the supra-occipital.

2. The large frontals (*Fr.*), which may or may not unite into one.

3. The nasal bones (*Na.*), apparently replaced in the Pike by the bones 1 and 2.

Fig. 46.

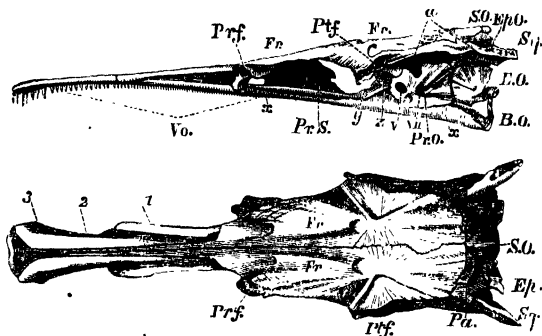


Fig. 46.—Side and upper views of the skull of a Pike (*Esox lucius*), without the facial or supra-orbital bones:—*y*, the basisphenoid; *z*, the alisphenoid; *a*, the articular facet for the hyomandibular bone.

The under-surface of the skull possesses two membrane bones: in front the *vomer* (*Vo.*), and, behind, the huge *parasphenoid* (*x, x*), which ensheathes all the *basis cranii*, from the basi-occipital to the vomer.

A supra-orbital bone (*S.Or.*) is the only membrane bone attached to the sides of the brain-case. Two premaxillary bones (*Pmx.*) are attached, sometimes closely, sometimes loosely, to the anterior extremity of the cranium; and behind these are the maxillæ (*Mx.*), which are sometimes large and single, as in the Cyprinoid fishes, but may become subdivided, or be reduced to mere styliform supports for cirri, as in many Siluroid fishes. In most osseous fishes the maxillæ

take little or no share in the formation of the gape, which is bounded above by the backwardly extended premaxillæ.

Fig. 47.

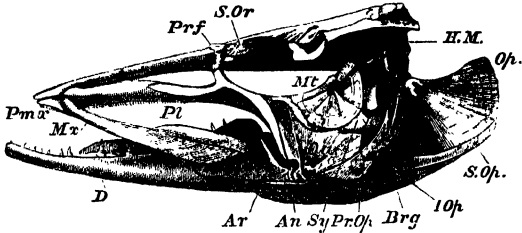


Fig. 47.—Side-view of the skull of a Pike (*Esox lucius*):—*Prf*, pre-frontal; *H.M.*, hyomandibular bone; *Op.*, operculum; *S.Op.*, sub-operculum; *I.Op.*, interoperculum; *Pr.Op.*, preoperculum; *Brg.*, branchiostegal rays; *Sy.*, symplectic; *Mt.*, metapterygoid; *Pl.*, palato-ptyergoid arch; *Qu.*, quadrate bone; *Ar.*, articular; *An.*, angular; *D.*, dentary; *S.Or.*, suborbital bone.

Fig. 48.

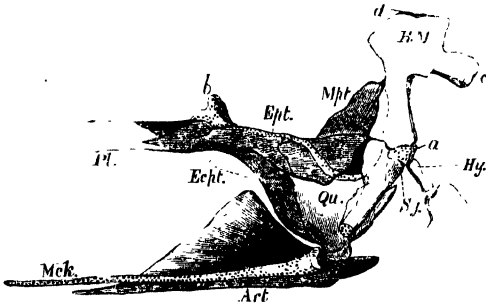


Fig. 48.—Palato-quadrato arch, with the hyomandibular and symplectic of the Pike, viewed from the inner side; the articular piece (*Art.*) of the lower jaw, and Meckel's cartilage (*Mck.*) of the Pike; seen from the inner side:—*a*, the cartilage interposed between the hyomandibular (*H.M.*), and the symplectic (*Sy.*); *b*, that which serves as a pedicle to the pterygo-palatine arch; *c*, process of the hyomandibular with which the operculum articulates; *d*, head of the hyomandibular which articulates with the skull.

The palato-quadrate and hyomandibular have essentially the same structure and arrangement as in *Lepidosteus* and *Amia*. The homologue of the suspensorium of the *Elasmobranchii* is articulated with a surface furnished to it by the postfrontal, pterotic, and pro-otic bones. Usually it moves freely upon that surface, but, in the *Plectognathi*, it may be fixed. It ossifies so as to give rise to two bones: an upper broad *hyomandibular* (*H.M.*), with which the operculum articulates; and a lower styloform *symplectic* (*Sy.*), which fits into a groove on the inner and posterior surface of the quadrate, and is firmly held there.

The palato-quadrate arch is represented by several bones, of which the most constant are the palatine (*Pl.*) in front, and the quadrate (*Qu.*) behind and below. Besides these there may be three others: an external, *ectopterygoid* (*Ecpt.*), an internal, *entopterygoid* (*Ept.*), and a *metapterygoid* (*Mpt.*). The last envelopes the upper and posterior portion of the primitive quadrate cartilage; and, fixing itself against the hyomandibular, contributes to the firmness of the union already effected by the symplectic.

Meckel's cartilage (*Mck.*) persists throughout life, but the ossification of its proximal end gives rise to an *os articulare* in the lower jaw. To these an angular (*An.*) and a dentary (*D.*) membrane bone are commonly added (Fig. 47).

The hyoidean arch is usually composed of two large cornua—connected with the cartilaginous interval between the hyomandibular and the symplectic by a *stylohyal* ossification, and abutting, in the middle line below, upon one or more median pieces, the anterior of which (*entoglossal*) supports the tongue, while the posterior (*urohyal*) extends back to join the median elements of the branchial apparatus. The cornua themselves are usually ossified into four pieces: an upper (*epihyal*) and a lower (*ceratohyal*) large ossification, and two small ones (*basihyals*) connected with the ventral ends of the lower large ossification.

There are usually five pair of branchial arches connected by median ventral ossifications. The posterior pair are single bones, which underlie the floor of the pharynx, bear

No branchial filaments, but commonly support teeth, and are called *hypopharyngeal* bones. In certain osseous fishes, hence called *Pharyngognathi*, they ankylose together into one bone. The anterior four pair are composed of several joints, and the uppermost articulations of more or fewer of them usually expand, bear teeth, and form the *epipharyngeal* bones. Sundry important membrane bones are connected with the mandibular and hyoidean arches. The *preoperculum* (*P.Op.*), *operculum* (*Op.*), and *branchiostegal* rays (*Br.*), already met with among the *Ganoidei*, are the most constant of these. Beneath the operculum, lies a *suboperculum* (*S.Op.*), and below this an *interoperculum* (*I.Op.*), which is connected by ligament with the angular piece of the lower jaw, and is also united to the outer face of the hyoidean arch. It may be altogether ligamentous, as in the Siluroids.

The branchiostegal rays are attached partly to the inner, and partly to the outer, surface of the hyoidean arch. They support a membrane, the *branchiostegal membrane*, which serves as a sort of inner gill-cover.

Most *Teleostei* possess two pair of limbs, the pectoral and the ventral fins. But the latter are often absent, and the former are occasionally wanting. When the pectoral fins are absent, the pectoral arch usually remains, though it may be reduced to little more than a filament, as in *Muraenophis*. The ventral fins are frequently situated in their normal position beneath the posterior part of the trunk; but in considerable groups of these fishes they are immediately behind the pectoral fins (*thoracic*), or even in front of them (*angular*). In the asymmetrical *Pleuronectida* one pectoral may be larger than the other, or may alone remain, as in *Monochirus*.

The pectoral arch always consists of a primarily cartilaginous *coraco-scapular* portion—which usually ossifies in two pieces, a coracoid below, and a scapula above—and of sundry membrane bones. The chief of these membrane bones is the *clavicula* (*Cl.*), which meets its fellow in the middle line, and is usually joined to it by ligament, but sometimes, as